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Contract No: N62467-70-C-0240

JET ENGINE TEST CELL
TEST AUGMENTER-SCRUBBER SYSTEM

FINAL REPORT December 1971

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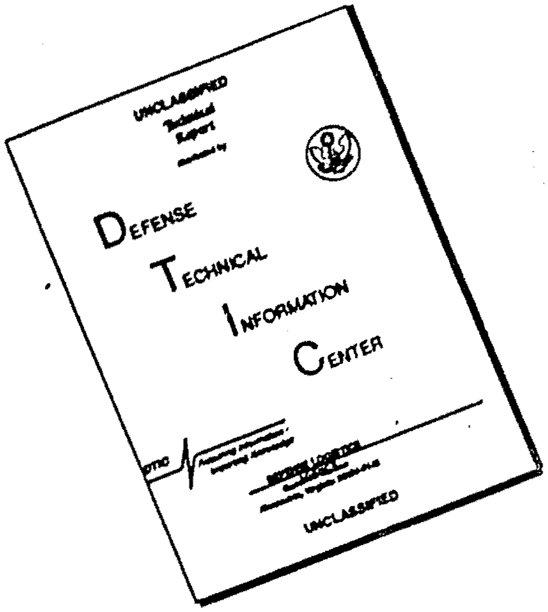

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CONTRACT N62467-70-C-0240
REPORT ON ABATEMENT OF PARTICULATE EMISSIONS AND NOISE FROM JET ENGINE TEST CELLS INCLUDING REDUCTION OF GAS FLOW WITH THE TESI AUGMENTER-SCRUBBER SYSTEM

December 1971

By:

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ABSTRACT

The prototype scrubber and augmentation system designed for and operated in Black Point Test Cell Number 1 NARF-Jacksonville has abated emissions to the projected design level. The engines operated with the system were the J-79, TF-30, and J-52. Particulate emissions were reduced to the 0.002-0.005 gr/SCF level. The visible emissions fell well within the Ringleman 1/2 level after dissipation of the steam plume. No fallout was evident during operation of the system. It was further established that engine test performance was not affected by the TESI system.

The scrubber system was mounted on the exhaust stack of the cell thus obviating the necessity for costly ducting and the requirement for ground utilization.

The size requirement of the scrubber was reduced significantly with the use of a new augmenter design that decreased the induced air to jet exhaust flow ratio from values in the range of 2:1 to 0.4-0.6:1. This new augmenter can reduce the augmentation even further, thus providing the potential of retrofit of existing cells to accommodate engines larger than now being tested. Sound levels were reduced by the installation of the scrubber from 6-10 decibels (dBA), where the original sound level was of the order of 90-95 dBA.

In order to prevent the mere transfer of pollution from airborne to waterborne, a loop system should be considered for all installations. The TESI scrubber recovers 74-96% of the energy of combustion in the engine and recovers up to 95% of the submicron particulates (up to 1/2 ton/day). Thus clean-up and cooling of the water with total recycle is necessary for all installations.

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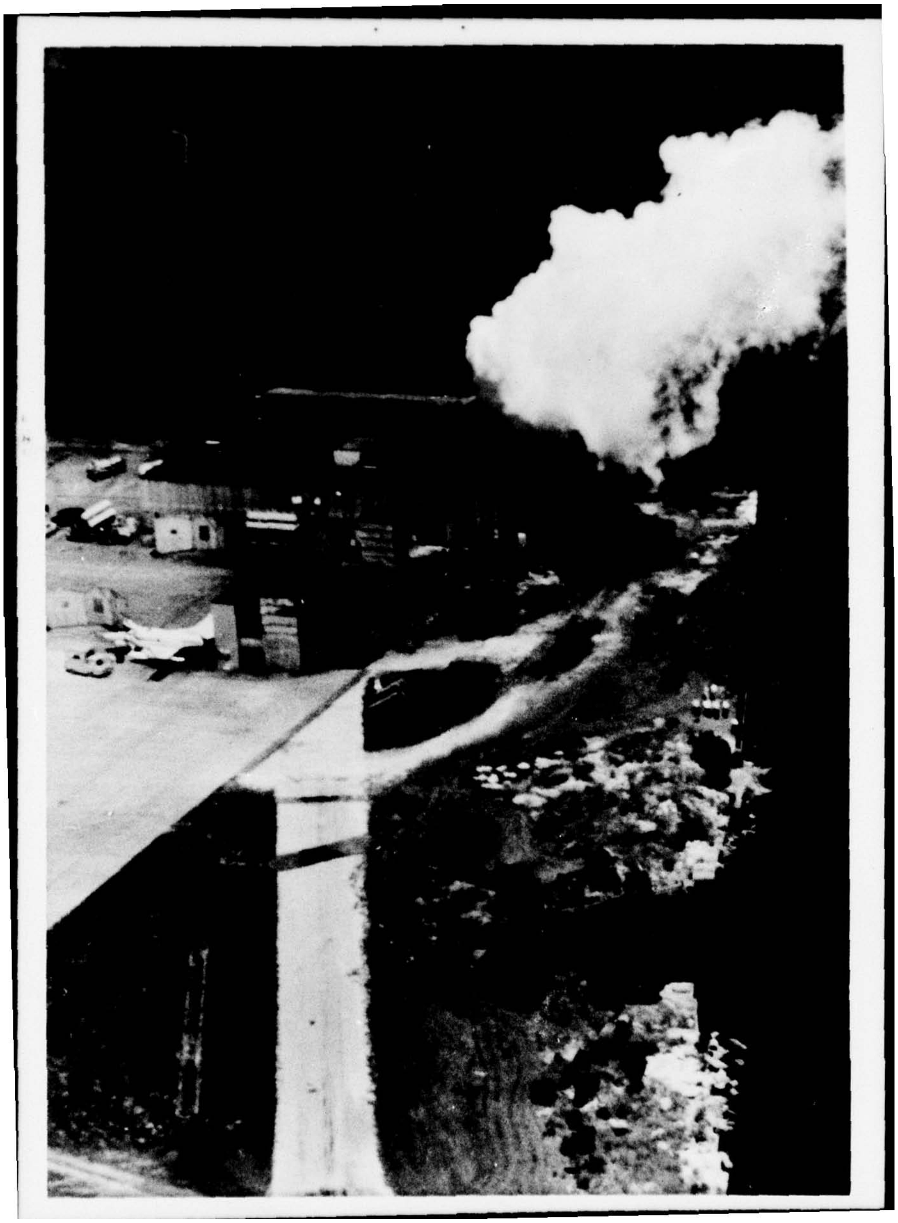


PART I
Chapter I

OVERVIEW: Overall Task

1.1 The task for this project was established by NAVFAC, Southern Division, as follows:

A. General Requirements

The Engineering Service Contractor shall perform the following services:

1. Determine by field test with test cell 774 operating in its present configuration; (a) types of pollutants emitted, (b) flow rates at appropriate points in the cell, (c) operating pressures and temperatures at appropriate points in the cell, (d) noise levels, (e) Ringleman test of effluent, and (f) other operating data that may be required to design a nucleation type scrubber system, and to determine by post installation test, its effectiveness.

2. Design a nucleation type scrubber system and an augmentation system for the test cell which will abate pollution to a degree commensurate with local and Federal regulations and which will conform to other local and Federal regulations (such as thermal and particulate pollution of water). Design should provide for use of any materials available at NARF, Jacksonville.

3. Erection of the design system, including necessary alterations.

4. Accomplish post installation tests necessary to determine the effectiveness of the scrubber and to establish the validity of the augmentation formula derived under contract N62467-70-C-0078.

5. Based upon tests in item 4 above, determine and accomplish modifications and/or adjustments required to optimize the operation of the abatement system.

6. Retest as necessary to determine effectiveness of the final system.

1.1 A. General Requirements (Continued)

7. Prepare a report evaluating performance of the abatement and augmentation systems and recommending criteria and design parameters to be used in modifying other existing test cells and constructing new cells for the abatement of pollutant emission.

NOTES: All tests other than air pollution tests will be provided by NARF, Jacksonville personnel. Testing done under this contract shall be accomplished by subcontract with an approved firm with demonstrated capabilities for the testing involved. The final test in item 6 above shall be scheduled so as to permit observation by various Government representatives to be determined. Pollution tests will be accomplished as follows:

	Test Before Any Modification	Test Prior To Optimization	Final Test
J-79-8	x	x	x
CBC Engine (Probably J-52 P8)	x		x

This report fulfills Task 7.

1.2 TESI wishes to acknowledge the aid and cooperation of members of NAVAIR, NAVFAC and NARF-JAX in bringing this system to its state of operation. As a result of this aid, the task requirements have been exceeded in the following areas:

1. 3 engines were tested rather than 2 (by mutual agreement).

2. Gas analyses were made to include loadings and particle size as well as Ringleman.

3. Gas flows through the test cell were reduced up to 1/2 of the conventional flow.

OVERVIEW: Summary

2.1 Evaluation of the performance of the test system for pollution abatement of operating effluents from a jet engine test cell was conducted at NARF, Jacksonville, Black Point Cell No. 1, during the period from December 1970 through May 1971. Characteristics of performance were obtained with the following engines:

J-52
J-79
TF-30

under operating conditions of idle through afterburner throttle setting conditions where applicable.

2.2 The results of the tests are as follows:

2.2.1 Abatement of particulate emissions was achieved for all engines at all conditions of test to well within all existing codes and regulations. The system performed in accordance with design projections for particulate emissions.

Existing codes call for Ringleman 1/2 as emission equivalent opacity after evaporation of steam. Executive Order 11282 implies a requirement of 0.008 grains/cu. ft. Design projection was 0.004 grains/ cu. ft.

The effluents from the system were:

J-52	Average	0.0026	grains/cu. ft.
TF-30	Average	0.0017	grains/cu. ft.
J-79	Average	0.0044	grains/cu. ft.

The Ringleman equivalent after dissipation of the steam was below Ringleman 1/2.

2.2.2 Reduction in total gas flow in the test cell in the order to 38-47% was achieved via use of the proprietary augmenter. The reductions in augmentation flows were as follows:

TABLE 2.1

EFFECT OF NEW AUGMENTER ON SECONDARY AIR FLOW

	Augmentation Ratio			Percent Reduction in Augmentation Air with New Aug	
		NEW AUG			
	Initial	36"D Throat	30"D Throat	36"D Throat	30"D Throat
J-79 Mil	2.1[1]	1.06[2]		50	
J-79 A/B	1.9[1]	0.64[3]		67	
TF-30 Mil	1.22[1]	0.62	0.38	49	69
TF-30 Mil	2.12	0.62	0.38	71	82

1 - Forcing cone placed on old augmenter. The forcing cone reduced augmentation 50% below conventional operation.

2 - All positions except 16" (See Table 7-3)

3 - All at position +2" (Reading 1.06 - 100% variation from other four deleted).

2.2.2. (Continued)

Overall flow reduction through the test cell was:

		Reduction in Total Flow - (%)	
		Large Cone	Small Cone
J-79[1]	Mil	34	
J-79[1]	A/B	44	
TF-30[1]	Mil	27	38
TF-30[2]	Mil	49	56

1 - Comparison is with forcing cone on old augmenter.

2 - Comparison with forcing cone that had been normally used in the installation.

The objective of flow reduction was the decrease of size and cost of the abatement systems. The implications are that larger engines can now be tested in existing cells if appropriate changes to the thrust systems are made.

2.2.3 Sound levels were reduced from 6-10 decibels (dBA) after installation of the scrubber indicating potential for reduction of installation of high maintenance sound attenuation equipment in test cells where the scrubber is installed. All data with the scrubber in operation were taken in the northwest quadrant and thus included intake noise. The reduction in sound level, therefore, is considered conservative.

2.2.4 The test system has been in continuous operation since April 1971 in stable regime and providing effective reduction in test cell gas flow, abatement

2.2.4 (Continued)

of particulate emissions, and sound level reduction.

2.2.5 Effluent water temperatures exceeded those projected on the basis of estimated heat transfer coefficients in the scrubber. Whereas peak effluent water temperatures of 145°F had been anticipated, the water effluent temperature during J-79 A/B operation was 165°F to 168°F. During military operation for the J-79 (the hottest engine tested), the temperature rise at the surface of the river was of the order of 25°F, and 6°F at 1 foot below the surface at a distance of 40 feet from the discharge. A mathematical model based on average of 33% of the time in military throttle and 5% in afterburner with an average scrubber water temperature rise over the 5-hour operating period of 13.8°F, showed a 4°F average rise in river water at a distance of 100 ft from the discharge point. The actual temperature rise in the scrubber water for this type of cycle is 26.3°F. Thus, an average rise of 8°F would be projected.

2.2.6 Although SO_2 exhaust could be anticipated from the specifications of JP-5 fuel, the sulfur maximum in the fuel is rarely evident and SO_2 levels were always below 10 PPM in the exhaust.

2.2.7 The solids recovered in the scrubber are not consistent in behavioral characteristics. In some cases, settling rates indicated a 5-25 micron agglomerate as the major constituent. In other cases, a stable emulsion was evident. Separation and recycle studies are indicated.

OVERVIEW: Recommendations

Regarding the present installation, it is recommended that:

3.1 A prototype cooling tower be installed to provide for recirculation of the water through the system and preclude emission of particulate or thermal pollution into the river.

3.2 A solids and oil separation system be installed in the circuit to provide a sludge that can be added to the fuel in the boiler plant.

Regarding future installations, it is recommended that:

3.3 Consideration be given to augmenter design in order to maintain a minimum 400-500°F temperature in the mixed jet augmentation air flow prior to quench. A variable throat TESI augmenter can be used in order to properly minimize flow for engines of different exhaust nozzle diameter.

3.4 The slope of the packed scrubber be increased to prevent breakthrough of water from the sides.

3.5 Thorough consideration of angle of gaseous emission from the scrubber with regard to effect on sound levels be made.

OVERVIEW: Design Parameters, Criteria, and Costs

The size and operation of the scrubber were evaluated based on the performance of the prototype. As a result of this study, the following parameters were established:

4.1 Height of packed section can be increased to 20 feet without adverse effects on performance.

4.2 The size of the scrubber can be reduced from 10% to 20% based on the Jacksonville unit. Thus the face dimension of the scrubber could have been reduced from 960 ft^2 to 840 ft^2, thus reducing the length of the scrubber from 30 feet to 26 feet.

4.3 The scrubber can accept outlet flows in the range of 100 - 450 ft/min and inlet flows of 100-600 ft,/min.

4.4 Stability was maintained at an irrigation rate of 5-25 GPM/ft^2 of irrigation area. Face spray flux was effective in the order of 1-3 GPM/ft^2.

4.5 Effective operation is achieved with irrigation with water in the range of 1-3 GPM per 100 CFM of outlet gas, as a function of inlet gas temperature.

4.6 A demister zone of 1 ft. of 1-inch Tellerettes is required.

4.7 Pressure drop of 6 in. w.g. should be considered as a maximum, although in operations, reliable data indicated that a maximum of 3-4 in. w.g. occurred.

4.8 The system was designed for 10 in. w.g. static pressure and was effective.

4.9 Top roll turning vanes should be used at the top of the scrubber.

4.10 The maximum operating temperature of the packing should be 175°F.

4.11 The cooling tower load, based on performance data, was higher than that predicted because of the high heat transfer rates. The thermal absorption is a function of the inlet temperature of the quenched gas. It represented 83-96% of the thermal value of the fuel burned when the quenched gas temperature was below 140°F and 74% of the thermal value of the fuel burned at an inlet temperature of 172°F.

4.12 The cost of the scrubber installed, exclusive of piping and pumps that will vary with the installation and engines tested, is of the order of 25¢ to 45¢ per ACFM inlet to the scrubber. This variation is a function of the dimensions of the stack and the height above the ground level.

The cost of the cooling tower, exclusive of pumps, piping, and sump is estimated to range from 0.14-0.25¢/(Btu/hr) for "average" design conditions and 0.05-0.10¢/(Btu/hr) for the responsive proprietary system at the maximum load condition. The ground space will range from 5 to 10 ft^2 per 10^6 Btu/hr at "average" design and 2 to 4 ft^2 per 10^6 Btu/hr at maximum conditions.

PART II
Chapter 5

DESIGN CONSIDERATIONS: TEST SCRUBBER

5.1 Description:

The TEST Scrubber (Fig. 5-1) is a cross flow nucleation system (proprietary) that provides for collection of submicron particulates via the nucleation phenomenon (a combined process of particle growth via condensation, improved particulate collision resulting from wetting via condensation, and codiffusional drag).

The scrubber was designed as two identical reflection sections mounted with independent supports parallel to the 20 ft sides of the stack. The overall scrubber dimensions are 30 feet long x 20 feet high x 28'6" wide, including gullwings and sides. The packed sections have a face dimension of 30 ft x 17 ft and each contained a 4'6" depth of 2-inch nominal Tellerettes followed by a divider support plate and 9 inches of 1-inch nominal Tellerettes. The 2-inch packing was irrigated with 4000 GPM for each 30-foot section. The water feed is divided into two components, sprays at 20 PSIG washing the 30 ft x 17 ft face at the rate of 1000 GPM per section and top distributors irrigating the 4'6" depth of the 2-inch packing at the rate of 3000 GPM per section. The 1-inch Tellerettes (9-inch depth) are not irrigated and serve as a demister section.

The gas flow (quenched test cell gas) is distributed to the two packed section faces by turning vanes on each side of the stack. The face sprays are used for initial reduction in temperature as well as to protect the packing from any "hot spot conditions" resulting from incomplete quenching in the augmenter section.

After leaving the packed demister, the gas is directed upwards at an angle of 45° by gull wings mounted on the scrubber section.

The liquid effluent is collected in sloped bottom troughs containing baffles to prevent gas bypass. The collected liquid is discharged by gravity to the river via a sealed underflow weir and an overflow weir.

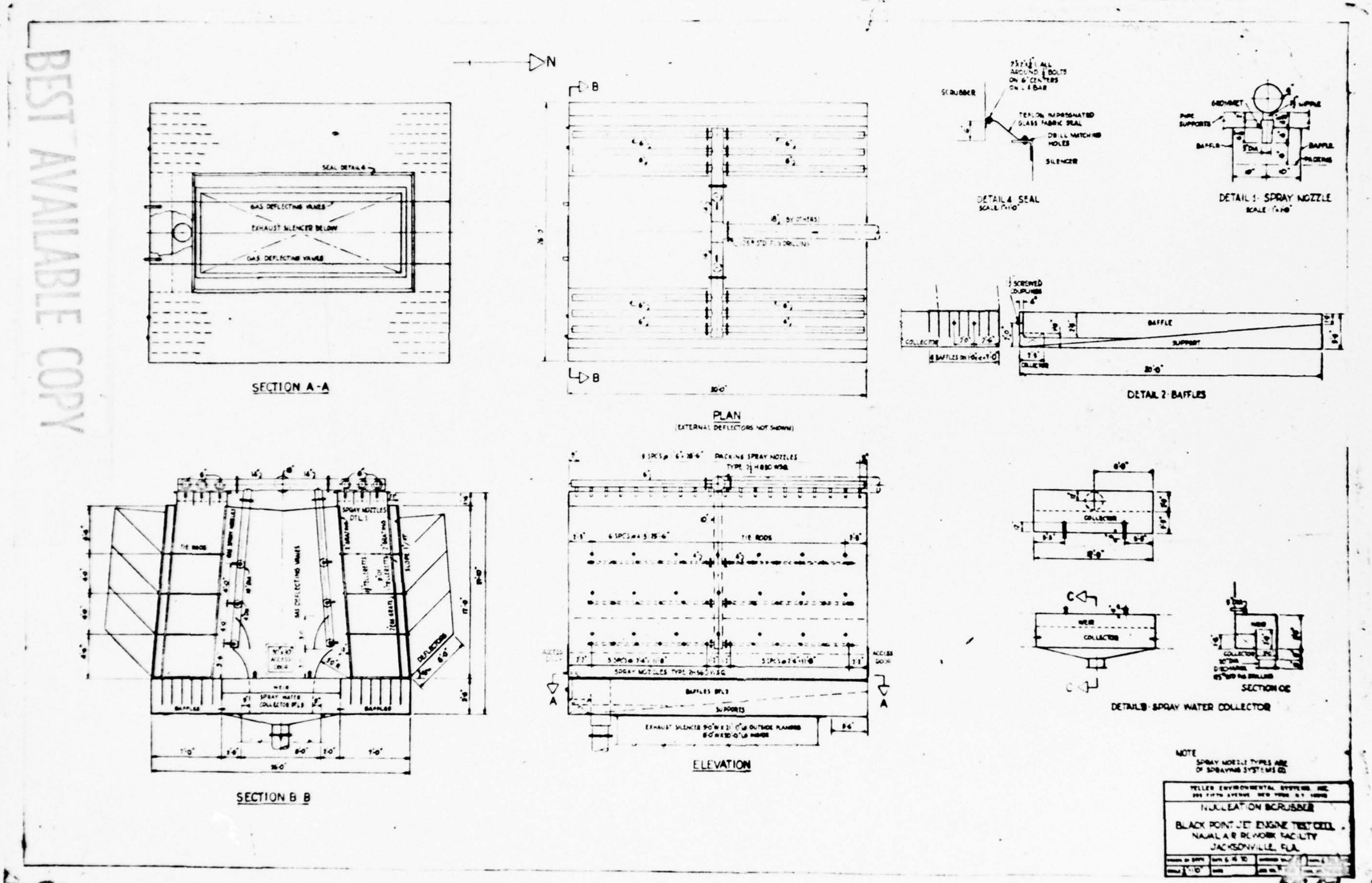
5.2 The characteristics of the scrubber are as follows:

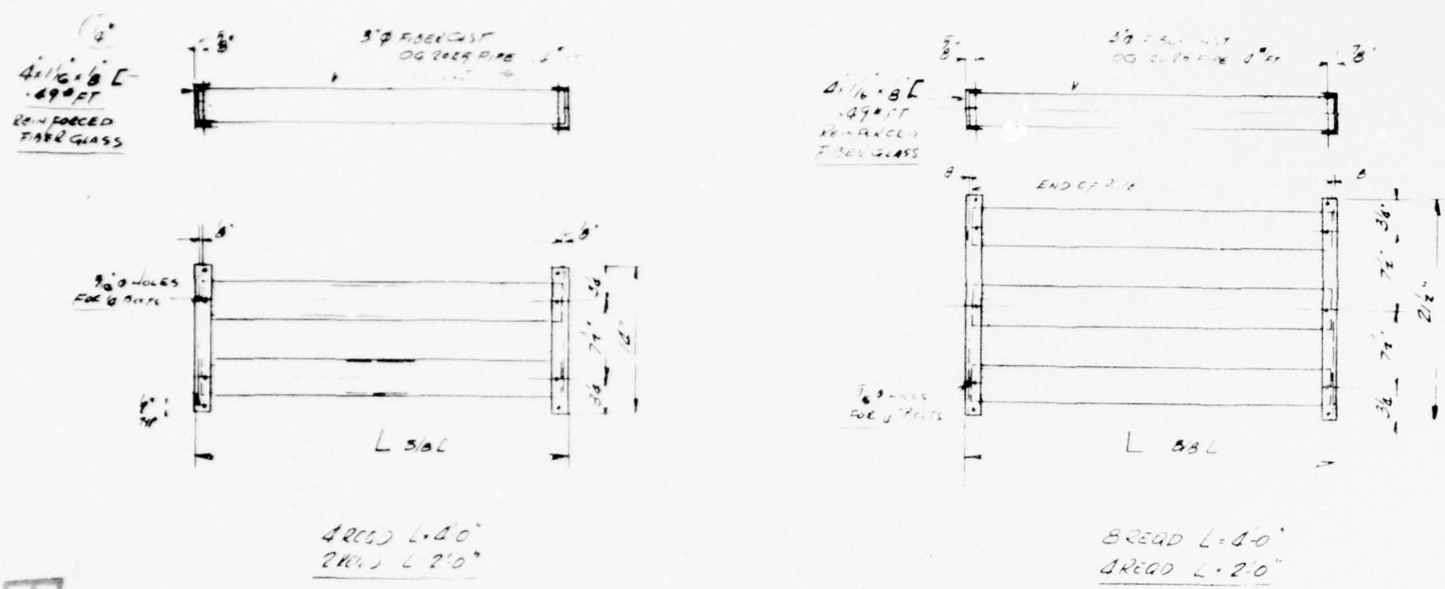
No. of scrubbers	-	2
Type of scrubber	-	Packed, cross flow, nucleation
Face Dimension for Gas Flow, Each Scrubber	-	30' x 17'
Depth of Packing	-	4'6" - 2" Tellerettes for cross flow nucleation 9" - 1" Tellerettes for demisting
Volume of Packing	-	4600 cu.ft. - 2" Tellerettes 770 cu.ft. - 1" Tellerettes
Grating	-	Polyethylene 1" x 1" grating with 2" shelves for strength.
Separation between Recovery and Demisting Sections	-	Polyethylene grating with 1" x 1" mesh cover.
Face Sprays	-	4 each section (4"D) - 8 total; 29' long, 8 nozzles per distributor
Top Distributor	-	3 (6"D x 30') each scrubber section - 6 total. Each distributor 20 nozzles (120 total)
Top Baffles	-	2 each side, 4 total 2'6" x 30' each.

5.2 (Continued)

Bottom Baffles	-	6 on 1-foot centers following full length of sump with 2' x 4" notches at deep end.
Bottom Sump	-	2 required, 1 for each scrubber; 30' long x 7' wide x 1' deep at shallow end and 3/6" deep at flooded end - Discharge through 24" D pipe.
Gull Wings	-	4 on each section of scrubber - 8 total. 6' x 30' each.
Turning Vanes	-	2 each side - 4 total. 2-3' Radius, 2-6' Radius plus straight sections - Epoxy painted steel.
Cover Sections	-	Corrugated FRP - Fiberglass reinforced plastic

Pipe baffles (FRP) were added at the top section of the existing stack because of severe maldistribution of gas flow entering the scrubber section. These were placed on the south end of the scrubber. Baffles consisted of 4' lengths of 3" D FRP pipe mounted on 7-1/2" centers (Fig. 5-2). The scrubber is independently supported. The top of the trough is breeched to the top of the stack by 1/4" thick Neoprene sheet.


SECTION A-A
SEAL DETAIL 4
GAS DEFLECTING VANES
EXHAUST SILENCER BELOW
GAS DEFLECTING VANES
PLAN
(EXTERNAL DEFLECTORS NOT SHOWN)
30'-0"
DETAIL 4 SEAL
SCRUBBER
TEFLON IMPREGNATED GLASS FABRIC SEAL
DRILL MATCHING HOLES
SILENCER
DETAIL 1 SPRAY NOZZLE
GROMMET
PIPE SUPPORTS
BAFFLE
PACKING
DETAIL 2 BAFFLES
SCREWED COUPLINGS
BAFFLE
SUPPORT
COLLECTOR
20'-0"
SECTION B-B
SPRAY NOZZLES DTL 1
TIE RODS
GAS DEFLECTING VANES
DEFLECTORS
SPRAY WATER COLLECTOR DTL 3
BAFFLES
36'-0"
ELEVATION
PACKING SPRAY NOZZLES
TIE RODS
ACCESS DOOR
SPRAY NOZZLES
BAFFLES DTL 2
SUPPORTS
DETAIL 3 SPRAY WATER COLLECTOR
COLLECTOR
WEIR
SECTION C-C
NOTE
SPRAY NOZZLE TYPES ARE OF SPRAYING SYSTEMS CO.
TELLER ENVIRONMENTAL SYSTEMS, INC.
NUCLEATION SCRUBBER
BLACK POINT JET ENGINE TEST CELL
NAVAL AIR REWORK FACILITY
JACKSONVILLE, FLA.



REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

LIST OF MATERIALS OR PARTS LIST

QTY REQD	SYM	NOMENCLATURE OR DESCRIPTION	CODE IDENT	PART OR IDENTIFYING NO	SPECIFICATION	MATERIAL OR NOTE	UNIT WT	ZONE	ITEM NO

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS DECIMALS ANGLES

MATERIAL

FINISH

NEXT ASSY | USED ON

APPLICATION

DRAWING STARTED 3-22-71 DATE

DRAWN

CHECKED

ENGR

TELLER ENVIRONMENTAL SYSTEMS, INC.
NEW YORK, N. Y.

AIR BAFFLES

NAVAL AIR REWORK FACILITY
JACKSONVILLE FLA

SIZE C | CODE IDENT NO | P-103-218

SCALE | SHEET

FIG. 5-2

PART II
Chapter 6

DESIGN CONSIDERATIONS: Water System

6.1 The water system for the TEST scrubber-augmenter unit consists of two major components:

1- River water for packed scrubber

2- Fresh water for augmenter

The flow diagram for the system, is indicated in Figure 6-1. The water intake system is shown in Figure 6-2.

6.2 River water is pumped at the rate of 8000 GPM (81 foot head) by a Johnston Vertical Mixed Flow Right Angle Drive 2-Stage Pump, Model F-250, driven by a 250 HP Diesel Engine, Cummins Model NT 280-1F. The intake of the pump submerged in the river was placed approximately 250 feet from the bulkhead, to achieve proper submergence. The 18" D carbon steel transfer line to the scrubber was approximately 350 feet long. Flow was measured by a by-pass orifice flowmeter. The discharge from the scrubber was 20"D and was placed along the bulkhead discharging at rip rap into the river at a 260 feet distance from the scrubber. The displacement of inlet and outlet, 540 feet on an east-west line and 120 feet on a north-south line, was chosen to minimize the potential of recycle to the scrubber. No evidence of recycle was observed.

6.3 The quench water was supplied from two (2) 20,000 gallon tanks with common feed from the station potable water system. Two pumps were used to provide water under head to the quench zone, one for the venturi throat spray ring and one for the diverging section sprays. The pumps were started by the test cell operator with starter switches in the control room.

The spray ring pump specifications were:

Ketchum Pump Model 3 ADIO
Head 175 ft.
600 GPM
50 HP Motor

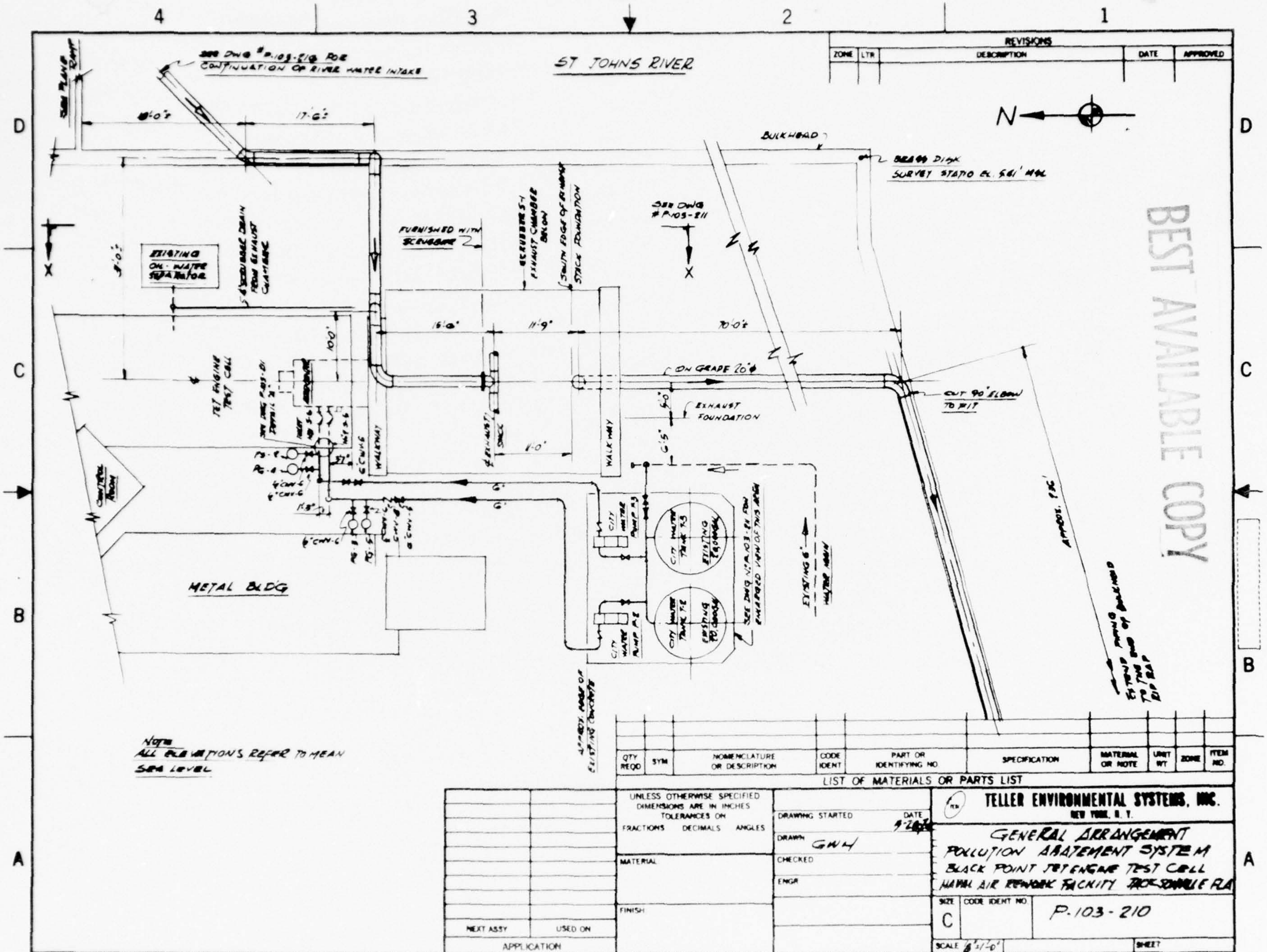

REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
ST JOHNS RIVER
SEE DWG # P-103-212 FOR CONTINUATION OF RIVER WATER INTAKE
SEA PLANE RAMP
BULKHEAD
BRASS DISK SURVEY STATION EL. 5.61' MSL
SEE DWG # P-103-211
EXISTING OIL-WATER SEPARATOR
FURNISHED WITH SCRUBBER
SCRUBBER S-1 EXHAUST CHAMBER BELOW
SOUTH EDGE OF EXHAUST STACK FOUNDATION
ON GRADE 20" Ø
CUT 90° ELBOW TO FIT
EXHAUST FOUNDATION
EXHAUST STACK
WALKWAY
JET ENGINE TEST CELL
CONTROL ROOM
METAL BLDG
CITY WATER TANK T-3 EXISTING 10,000 GAL
CITY WATER TANK T-2 EXISTING 10,000 GAL
CITY WATER PUMP P-3
CITY WATER PUMP P-2
SEE DWG NO. P-103-214 FOR ENLARGED VIEW OF THIS AREA
EXISTING 6" WATER MAIN
APPROX. EDGE OF EXISTING CONCRETE
APPROX. 1 3/4"
EXISTING PIPING TO THE END OF BULKHEAD
NOTE ALL ELEVATIONS REFER TO MEAN SEA LEVEL
QTY REQD | SYM | NOMENCLATURE OR DESCRIPTION | CODE IDENT | PART OR IDENTIFYING NO | SPECIFICATION | MATERIAL OR NOTE | UNIT WT | ZONE | ITEM NO.
LIST OF MATERIALS OR PARTS LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES
MATERIAL
FINISH
NEXT ASSY | USED ON
APPLICATION
DRAWING STARTED
DATE
DRAWN GWH
CHECKED
ENGR
TELLER ENVIRONMENTAL SYSTEMS, INC. NEW YORK, N. Y.
GENERAL ARRANGEMENT
POLLUTION ABATEMENT SYSTEM
BLACK POINT JET ENGINE TEST CELL
NAVAL AIR REWORK FACILITY JACKSONVILLE FLA
SIZE C
CODE IDENT NO
P-103-210
SCALE
SHEET

FIG G-1

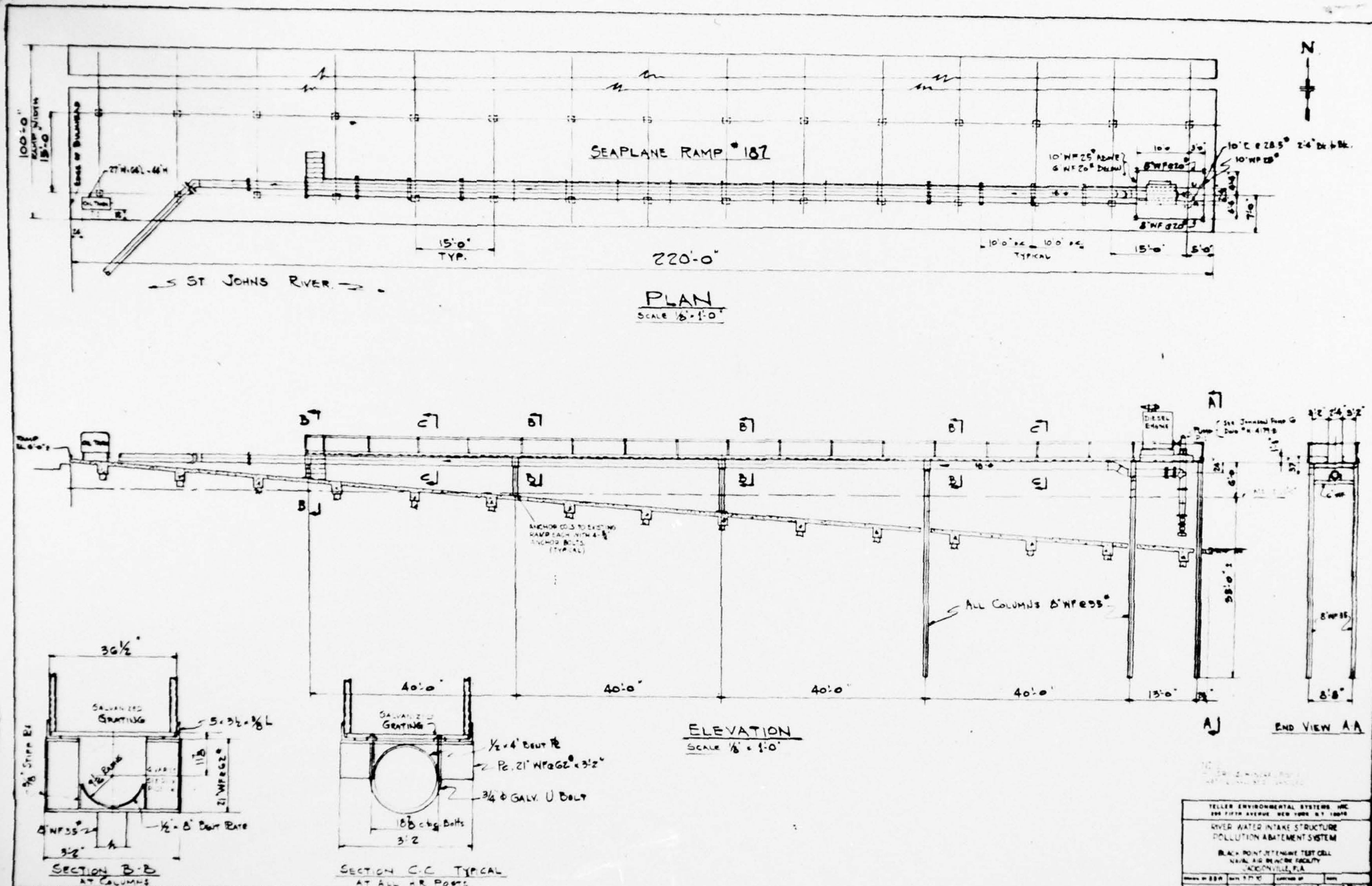

N
SEAPLANE RAMP #187
100'-0"
RAMP WIDTH
18'-0"
EDGE OF BULKHEAD
15'-0"
TYP.
220'-0"
15'-0"
5'-0"
ST JOHNS RIVER
PLAN
SCALE 1/8" = 1'-0"
DIESEL ENGINE
ALL COLUMNS 8"WF@35#
ANCHOR COLS TO EXISTING RAMP EACH WITH 4-5/8" ANCHOR BOLTS (TYPICAL)
40'-0"
40'-0"
40'-0"
40'-0"
13'-0"
ELEVATION
SCALE 1/8" = 1'-0"
END VIEW A-A
36 1/2"
GALVANIZED GRATING
5 × 3 1/2 × 3/8 L
21"WF@62#
1/2 × 8" BENT PLATE
SECTION B-B
AT COLUMNS
GALVANIZED GRATING
1/2 × 4" BENT PL
PL. 21" WF@62# × 3'-2"
3/4 Φ GALV. U BOLT
3'-2
SECTION C-C TYPICAL
AT ALL HR POSTS
TELLER ENVIRONMENTAL SYSTEMS, INC.
RIVER WATER INTAKE STRUCTURE
POLLUTION ABATEMENT SYSTEM
BLACK POINT JET ENGINE TEST CELL
NAVAL AIR REWORK FACILITY
JACKSONVILLE, FLA

FIG. 6-2

6.3 (Continued)

The diverging section spray pump provided by the U. S. Navy was a:

Ketchum Pump Model 5874
Head 175 ft.
500 GPM
30 HP Motor

The water feed to the augmenter was delivered through 6"D lines with positive shutoffs controlled from the test cell operating room.

DESIGN CONSIDERATIONS: Augmenter

7.1 The augmenter system (Fig. 7-1)(6'4"D x 12') was designed to provide for reduction of augmentation with minimal or no physical interference with the flow of the jet. The flow system was conceived as follows:

7.1.1 Converging throat (25°) as entrance for the jet exhaust stream. The throat diameter, 3'0" is 6" greater than the exhaust bell diameter of the largest engine to be tested.

7.1.2 A minimum horizontal open distance of 1'0" with no directional structure before the position of the diverging venturi section (∿7°). The open space houses the recessed high velocity spray ring and the remaining annular area for recycle flow.

7.1.3 The recessed annular spray ring is a 6"D pipe rolled to a 4'0" centerline diameter and perforated with 1/4"D spray orifices (40). These spray orifices direct the flow at a velocity of 80 fps radially into the jet exhaust stream.

7.1.4 The diverging section of the venturi, expanding at a half angle of approximately 7°, is hollow and is perforated with 1/4"D orifices to provide secondary quench water at 60 ft/sec to 80 ft/sec. The outer diameter of the diverging section is 4'7", thus providing an annular cross section between the diverging section and the augmenter I.D. of 13.1 ft^2. This represents 41.8% of the total augmenter cross section, and is the flow area for the recycle gas.

7.1.5 A recycle circular baffle is placed 1'8" downstream from the end of the diverging conical section in

7.1.5 (Continued)

order to aid the recycle of the quenched gas. The flange height is 4" and can act as a baffle. One additional baffle was provided to increase the scoop baffle height to 12".

7.1.6 A removable axially located hollow conical core buster was located with the leading point 6" upstream of the trailing edge of the diverging section. This unit was placed in the augmenter to determine the necessity for final breaking of the jet core. The core buster was 32-1/4"D orifices for secondary irrigation and quenching.

BASIS OF DESIGN

7.2 The objective of this augmenter system (Fig. 7-1) was to minimize the total gas flow in the exhaust in order to reduce the capital cost and size of the pollution abatement system. The secondary objective was to reduce the total gas flow with the possibility resulting that the existing test cells, with thrust bed modification, could be used for the new, larger engines that are adopted by the Navy.

The design and development of this augmenter was based on the following:

Hypothesis 1: The presence of non-aerodynamic fixed bodies in the path of the jet exhaust, as a secondary effect, precludes reduction in augmentation because of the turbulence developed. As a result of turbulence occurring in augmenters with fixed bodies in the path of the gas stream, the engine must be blanketed with secondary air, in the order of augmentation of 1-3, in order to maintain engine stability.

7.2 (Continued)

Hypothesis 2: The kinetic energy of the exhaust, approximately 1/2 of the total energy in the A/B range (calculated), can be relieved by entrainment, turbulence, or pressure drop due to friction. The most effective mode is entrainment combined with friction loss in an area outside the main flow zone, because it minimizes reflection of instability to the engine. The design objective was to maintain, as much as feasible, the entrainment mechanism but to provide it, not with secondary air only, but with flashing water and an internal recycle. The annular space around the diverging section was the mechanism projected to achieve both these phenomena. Based on the cross sectional area of the annulus, the following *internal recycle augmentation* rates for the J-79 were projected:

TABLE 7.1

Effect of Recycle on Augmentation Ratio

Internal Recycle Velocity sfps	Recycle Flow SFCS	Recycle Flow lb/sec	Internal Augmentation Ratio
50	655	52.9	0.29
100	1310	105.8	0.59
150	1965	158.5	0.88
200	2620	211.6	1.08

Thus by air flow recycle alone, assuming an augmentation ratio of 2.0, reduction to ratios of 0.92 to 1.71 could be achieved within the recycle velocity range of 50 to 200 sfps, provided the

7.2 (Continued)

Hypothesis 2: (Continued)

recycle air is introduced at the venturi throat. If the recycle air does not return at the throat, no significant effect will occur. An additional and major factor for the reduction of augmentation is that the recycle flow, entering the augmenter at the throat of the venturi, carries unevaporated water in the stream. If it enters at the periphery of the jet exhaust, it can flash to a vapor thus satisfying a part of the need for jet exhaust entrainment. This type of augmentation is most desirable because it fulfills the system's dual need for thermal and momentum transfer. The steam augmentation is also condensible and, therefore, does not burden the pollution control system with non-condensible flow.

The problem in design was that the quantitative prediction of the quantity of droplet flow back to the throat is, to say the least, difficult. However, spray orifices were located near the trailing edge of the diverging section of the venturi in order to maximize the recycle quantity.

Hypothesis 3: The air scoop was incorporated in the design in order to maximize the recycle. The recycle phenomenon should occur because of decrease of the velocity of the gas stream as it expands into the diverging zone of the venturi. Inasmuch as the ratio of the two cross sections is 2.6, the system gas flow will have a ratio of 6.7 velocity heads. With a total augmentation ratio of 2 (sum of external, recycle, and flash), an increase in static pressure of 3 to 5 in. w.g. was estimated at the trailing edge of the diverging section of the venturi. This increase in static pressure is theoretically capable of causing a recycle rate in the annular section as high as 800 fps exclusive of friction and reversal losses.

7.2 (Continued)

Hypothesis 3: (Continued)

The air scoops were placed in the augmenter on an experimental basis in order to aid the turnaround.

Hypothesis 4: The core buster in aerodynamic form was placed, in removable condition, in the augmenter if final destruction of the jet core was required. The maximum jet diameter (J-79 AB) was 28 inches. Under these conditions, it would naturally dissipate at a distance of 20 feet from the engine discharge. Inasmuch as the augmenter was only 12 feet long, it was indicated that the possibility existed for presence of the hot core at the termination of the augmenter.

7.3 AUGMENTER - THEORETICAL EVALUATION

7.3.1 The use for augmentation in the test cell has been justified on the basis of cooling the exhaust gases from the jet engines for protection of structure and sound attenuation equipment, cooling of the engine, and stabilization of the engine. Thus, a large quantity of augmented air was desired as long as drag turbulence in the cell and the velocities in the acoustic treatment section were within acceptable limits. However, with the imposition of the pollution control, the total gas flow becomes critical because of its effect on capital and operating costs, and size of the pollution control system.

7.3.2 The objective of the TESI augmenter system was to minimize the non-condensible gas flow without affecting the engine operation. The theoretical evaluation was made to guide the achievement of this objective. The following assumptions were made in the model:

7.3.2 (Continued)

(i) Ideal gas law is valid.

(ii) Energy loss in droplet formation is negligible.

(iii) Gas leaving the augmenter is saturated with water vapor.

(iv) Frictional losses are considered negligible except for the recycle flow.

(v) Gases leave outlet stack at ambient pressure.

TABLE 7-2

NOMENCLATURE FOR AUGMENTER DERIVATION

Augmenting Air:

μ	Relative Mass Rate,	$\frac{\text{lbm/sec. of augmenting air}}{\text{lbm/sec. of engine exhaust}}$
Θ_a	Relative Temperature,	$\frac{\text{augmenting air temp., °R}}{\text{engine exhaust temp., °R}}$
P_a	Relative Pressure,	$\frac{\text{ambient air pressure}}{\text{engine exhaust pressure}}$
A_a	Relative Flow Area,	$\frac{\text{flow area for augmenting air}}{\text{area of engine exhaust}}$

Water:

ν	Relative Mass Rate,	$\frac{\text{lbm/sec. of water}}{\text{lbm/sec. of engine exhaust}}$
T_w	Temperature of water, °F	
λ	Latent heat of vaporization	
C_{p_w}	Specific heat of water	

7.3.2 TABLE 7-2 (Continued)

Water: (Continued)

X	Relative Velocity,	$\frac{\text{velocity of water}}{\text{velocity of engine exhaust}}$
Θ	angle of water injection with respect to axis of the augmenter.	

Engine Exhaust:

M_E	Mach No.
C_p	Specific heat of engine exhaust.
T_E	Temperature of engine exhaust, °R
γ	Specific heat ratio for engine exhaust
P_E	Engine exhaust pressure, PSIA
P_s	Relative ambient pressure, $\frac{14.7}{P_E}$

Outlet Flow:

Ψ	Relative Mass Rate,	$\frac{\text{lb /sec. of total outlet flow}}{\text{lbm/sec. of engine exhaust}}$
Θ_o	Relative Temperature,	$\frac{\text{outlet gas temperature, °R}}{\text{engine exhaust temperature, °R}}$
P_o	Relative Pressure,	$\frac{\text{outlet pressure}}{\text{engine exhaust pressure}}$
A_o	Relative area of Augmenter,	$\frac{\text{outlet flow area}}{\text{area of engine exhaust}}$
A_s	Relative stack area,	$\frac{\text{outlet stack area}}{\text{area of engine exhaust}}$

7.3.3 (Continued)

Momentum balance:

$$\frac{1}{\gamma M_E^2}\left\{1 + P_a A_a - A_o\left(P_o - P_{R_2}\right) - P_o A_o\right\} =$$

$$\frac{\Psi^2 \Theta_o}{P_o A_o} + \frac{\eta^2 \theta_o}{A_R}\left[\frac{1}{P_o} - \frac{1}{P_{R_2}}\right] - 1 - \frac{\mu^2 \theta_a}{P_a A_a} - \nu X \cos\Theta$$

7-2

Energy Balance:

$$1 + \mu\Theta_a' + \gamma\left[\frac{C_{P_W}\,T_W - \lambda}{C_P(T_E - 460)}\right] - \Psi\Theta_o' =$$

$$\left(\frac{\gamma - 1}{2}\right)\frac{M_E^{\,2}}{\left(1 - \frac{460}{T_E}\right)}\left\{\frac{\Psi^3\Theta_o^2}{P_o^2\,A_o^2} + \frac{\eta^3\Theta_o^2}{A_R^2}\left[\frac{1}{P_o^2} - \frac{1}{P_{R_2}^2}\right]\right.$$

$$\left. - 1 - \frac{\mu^3\Theta_a^2}{P_a^2\,A_a^2} - \nu X^2\right\}$$

7-3

where: $\Theta_a' = \dfrac{\Theta_a - k}{1 - k}$ and $\Theta_o' = \dfrac{\Theta_o - k}{1 - k}$ and

$$k = 460/T_E$$

7.3.3 (Continued)

Equation for Saturation Condition:

$$\ln\left(y_w \frac{P_o p_E \, 760}{14.7} \right) = 21.17 - \frac{9720}{\Theta_o T_E} \qquad 7.4$$

$$y_w = \frac{\left(\nu + \xi_a \mu + \xi_E\right)/18}{\left\{\left[\left(1-\xi_a\right)\mu + 1-\xi_E\right]/29\right\} + \left\{\left[\nu + \xi_a \mu + \xi_E\right]/18\right\}} \qquad 7\text{-}5$$

Outlet Pressure

$$P_o = P_s \frac{\left[1 + \left(\frac{\gamma-1}{2}\right) M_E^2 \frac{\Psi^2 \Theta_o}{A_s^2 P_s^2}\right]^{\frac{\gamma}{\gamma-1}}}{\left[1 + \left(\frac{\gamma-1}{2}\right) M_E^2 \frac{\Psi^2 \Theta_o}{A_o^2 P_o^2}\right]^{\frac{\gamma}{\gamma-1}}} \qquad 7\text{-}6$$

Pressure Drop through the Annulus:

$$P_o - P_{R_2} = 2f\left(\frac{L}{D}\right) \frac{\eta^2 \Theta_o}{A_R^2 \, P_o} \gamma M_E^2 \qquad 7\text{-}7$$

7.3.3 (Continued)

The above equations, derived for a fixed geometry and given engine parameters, are quite general. The variables in these equations are explained in TABLE 7-2). The variables - namely pressure, temperature, flow areas and mass rates - are made dimensionless based on the engine parameters.

Equations 7-1, 7-2, and 7-3 are conventional mass, momentum, and energy balances. Equations 7-4 and 7-5 relate the partial pressure of water at saturated conditions as a function of temperature in the range of 130°F-170°F. Equation 7-6 relates the augmenter outlet pressure as a function of the outlet velocity. Equation 7-7 describes the pressure drop for recycle flow assuming non-compressible isothermal flow.

The above equations 7-1 through 7-7 define the simplified augmenter flow conditions. In general, knowing the geometry and the engine exhaust parameters, there are eight unknowns:

$$\mu,\ \nu,\ \Psi,\ P_o,\ \Theta_o,\ Y_w,\ P_{R_2} \text{ and } \eta$$

Thus, it is possible to obtain the values of first seven unknown variables for an assumed value of the recycle. (η).

The major difference between this model and that presented in the initial report (Cont. No. N62467-70-C-0078) is consideration of the effect of saturation of the gas and the recycle phenomenon.

7.3.4 CALCULATIONS

The simultaneous solution of the design equations was carried out on a computer. The calculations were carried out for the following data:

7.3.4 (Continued)

(A)

	J-79-8 MAX A/B	TF-30-P8 MIL
Mass flow, lbm/sec	180	260
Temperature, °F	3140	618
Exhaust pressure, PSIA	36	28.9
Engine nozzle dia.,"	30-1/8	26-5/8
Dew Point, °F	80	80

(B) Ambient air:

Temperature = 80°F   Dew Point = 60°F

Pressure = 14.7 PSIA

(C) Water:

Temperature = 80°F   Injection Velocity = 80 ft/sec

Angle of Injection = 90°F

(D) Outlet Stack Area = 80 ft^2 Pressure at Outlet of Stack = 14.7 PSIA

(E) Recycle Flow Annulus:

Length: = 4.0 ft.   Equivalent dia. - 1.5 ft

Frictional coefficient = 0.05 (assumed)

7.4 DISCUSSIONS

7.4.1 In the earlier study (Contract No. N62467-70-C-0078),

7.4.1 (Continued)

pp. 20), it was established that the air augmentation could be minimized by manipulation of the augmenter dimensions. From the present theoretical study, the effect of changing augmenter dimensions is indicated in Figures 7-3 and 7-4, and TABLE 7-4).

7.4.2 The decrease in relative augmentation flow area at a constant outlet area brings about a decrease in augmentation ratio. (Figure 7-3). This effective "close-coupling" is dependent upon the engine location with respect to the inlet cone and the jet exhaust diameter. For example, for engine locations away from the inlet cone, the limiting constant and its magnitude is determined by the annulus between the engine exhaust core and the venturi throat, or radial distance to converging throat (if controlling). Thus beyond a given point, the distance of the tailpipe from the throat should not affect augmentation ratios greatly.

Therefore, it is implied that the augmentation ratio will be vary greatly with change of distance of the jet exhaust to the throat. This was confirmed with the TF-30 (TABLE 7-3). However, a 15% to 20% increase in augmentation was observed in the case of the J-79 (Military firing) at a critical distance change from 14" to the 16" position (TABLE 7-3).

For J-79-8 engine at Max. A/B rating, the engine location will be critical in that the limiting augmentation flow area could be determined by the clearance between the engine shroud and the inlet cone. With engine core expansion to a diameter of 33" at the 36" venturi throat, the relative augmentation flow area is 0.22 and, consequently, augmentation ratio was predicted to be about 0.65 (TABLE 7-4). These values of augmentation ratios are in range of the observed limits (0.55-0.94). (TABLE 7-3). The lower values of augmentation achieved in test work may be attributed to boundary eddies developing in the jet enhaust, resulting in an effective decrease of the augmentation area.

7.4.3 For a constant relative augmentation flow area, the augmenter performance with respect to variations in outlet

7.4.3 (Continued)

diameter is shown in Figure 7-4. As the downstream outlet diameter increases, the exhaust gases are slowed down and, consequently, the augmentation ratio is increased. Conversely, it is possible to decrease the augmentation ratio by decreasing the outlet diameter.

7.4.4 For the J-79-8 engine at Max. A/B condition, the calculative saturation temperature is in the range of 160°F-175°F and is relatively independent of the augmentation ratio.

7.4.5 At first glance, the theoretical analysis indicates (see computer results, TABLE 7-4) that for a given geometry, the recycle ratio does not affect the augmentation ratio. This behavior was observed in the actual data when the recycle flow was blanked off. Referring to Figure 7-4, it is seen that the augmentation increases with the increase in the outlet diameter for a constant augmentation flow area. Inasmuch as the presence of recycle flow has an effect of decreasing the outlet velocity, the total augmentation may increase. However, with the partial augmentation requirements supplied by the recycle flow, the induced non-condensible augmentation may still remain constant. It is believed that for the recycle flow to reduce the induced non-condensible augmentation, the injection of recycle flow must be obtained at the inlet cone such that simultaneous reduction in augmentation flow area is achieved. Inasmuch as this effect of reducing augmentation area by the recycle flow was not accounted for in the theoretical model, the theoretical analysis was incomplete and no augmentation effects were predicted.

7.4.6 In the earlier study (Contract No. N62467-70-C-0078, pp. 1-6), it was pointed out that the quench input downstream of the augmenter forcing cone would not affect the degree of augmentation. (Figure 7-5). This behavior is also established in Figure 7-3, where it is seen that augmentation ratio is essentially independent

7.4.6 (Continued)

of irrigation at a constant outlet area condition. Data obtained by NARF personnel for the TF-30 and J-79 engines indicated no statistically valid decrease in augmentation for the J-79 with introduction of 600 GPM of quench as opposed to no water and approximately 8% reduction (within range of accuracy of the data) for the TF-30 with the same water variation. (TABLE 7-4).

EFFECT OF TESI AUGMENTER ON TOTAL AIR FLOW

TABLE 7-3

ENGINE	AUGMENTER CONDITION	OPERATION MODE	QUENCH GPM	AUGMENTER RATIO	AIR FLOW LB/SEC
J52-P6	Old Augmenter	Military	0	1.9	411
J52-P8	New	Military	200	1.26	317
	New	Military	200	1.43	341
J52-8B CBC	New -aft position	Military	100	1.30	322
TF30-P8	Old Augmenter	Military	0	2.12	843
	Old Aug.+ F.C.	Military	0	1.11	569
	Old Aug.+ F.C.	Military	0	1.21	596
	Old Aug.+ F.C.	Military	0	1.34	633
	New -Mod. Cone	Military	200	0.38	373
	New - 7" clear	Military	150	0.60	433
	New -12" clear	Military	150	0.66	448
	New- 12" clear	Military	150	0.67	452
	New- 7" clear	Military	150	0.68	453
	New- -16" clear	Military	200	0.54	416
	New - 7" clear	Military	150	0.68	453
	New -16" clear	Military	200	0.54	416
TF30-P6	Old Aug.+ F.C.	Military	600	1.19	577
	Old Aug.+ F.C.	Military	0	1.3	622
J79-8B	Old Aug.+ F.C.	Military	0	2.1	561
	Old Aug.+ F.C.	Military	600	2.08	554
	New 16"	Military	200	1.25	405
	New 16"	Military	200	1.25	402
	New 14"	Military	200	1.06	371
	New 14"	Military	200	1.02	363
	New 2"	Military	200	1.06	371
	New 14"	Military	200	1.10	377
	Old Aug.+ F.C.	MAX A/B	600	1.9	521
	New + 2"	MAX A/B	1000	1.06	370
	New + 2"	MAX A/B	1000	0.55	278
	New + 14"	MAX A/B	1000	0.94	350
	New + 14"	MAX A/B	1000	0.79	323
	New + 14"	MAX A/B	1000	0.85	332
	New + 2"	MAX A/B	1000	0.78	320
	New + 14"	MAX A/B	1000	0.83	329
	New + 2"	MIN A/B	1000	0.82	327
J79-10	New + 2"	Military	200	0.99	359
	New - 10"	Military	200	1.14	384
	New + 2"	MAX A/B	1000	0.55	277
	New - 10"	MAX A/B	1000	0.68	303

TABLE 7.4 (A)

MODEL PREDICTED AUGMENTATION RATIOS
FOR J-79-8 ENGINE AT MAX A/B

Recircula-tion Ratio	Aug. Area Ratio	Outlet* Pressure ($IN-H_2O$)	Exhaust Area Ratio	Aug. Ratio	Irriga-tion Ratio	Sat. Temp (°F)
η	A_a	P_o	A_o	μ	ν	
0.0	0.10	-20.75	5.14	0.48	0.87	173
0.0	0.30	-31.10	5.14	0.77	0.80	167
0.0	0.50	-35.09	5.14	0.93	0.78	160
0.0	0.70	-37.56	5.14	1.00	0.77	158
0.0	0.90	-38.02	5.14	0.98	0.76	160
0.0	0.34	-23.38	6.00	1.10	0.86	165
0.0	0.34	-16.79	8.00	1.54	1.07	166
0.0	0.34	- 7.16	10.00	1.90	1.36	168
0.0	0.34	- 4.47	12.00	2.19	1.69	171
0.27	0.34	-32.26	5.14	0.82	0.80	166
0.41	0.34	-32.32	5.14	0.82	0.80	166
0.54	0.34	-32.42	5.14	0.82	0.80	166
0.68	0.34	-32.48	5.14	0.83	0.80	166
0.82	0.34	-32.53	5.14	0.83	0.80	166
0.95	0.34	-32.54	5.14	0.83	0.80	166
1.09	0.34	-32.45	5.14	0.82	0.80	166

*Static pressure in inches w.g. at the augmenter outlet.

NOTATION:

η - Recirculation Ratio

A_a - Augmentation Area Ratio

A_o - Exhaust Area Ratio

ν - Irrigation Ratio

TABLE 7.4 (B)

MODEL PREDICTED AUGMENTATION RATIOS
FOR TF-30-P8 ENGINE AT MIL

Recirculation Ratio	Aug. Area Ratio	Outlet* Pressure ($IN-H_2O$)	Exhaust Area Ratio	Aug. Ratio	Irrigation Ratio	Sat. Temp. (°F)
η	A_a	P_o	A_o	μ	ν	
0.0	0.10	-37.29	6.55	0.46	0.38	157
0.0	0.30	-42.27	6.55	0.79	0.27	143
0.0	0.50	-50.15	6.55	1.00	0.22	136
0.0	0.70	-55.23	6.55	1.17	0.20	131
0.0	0.80	-55.23	6.55	1.25	0.19	129

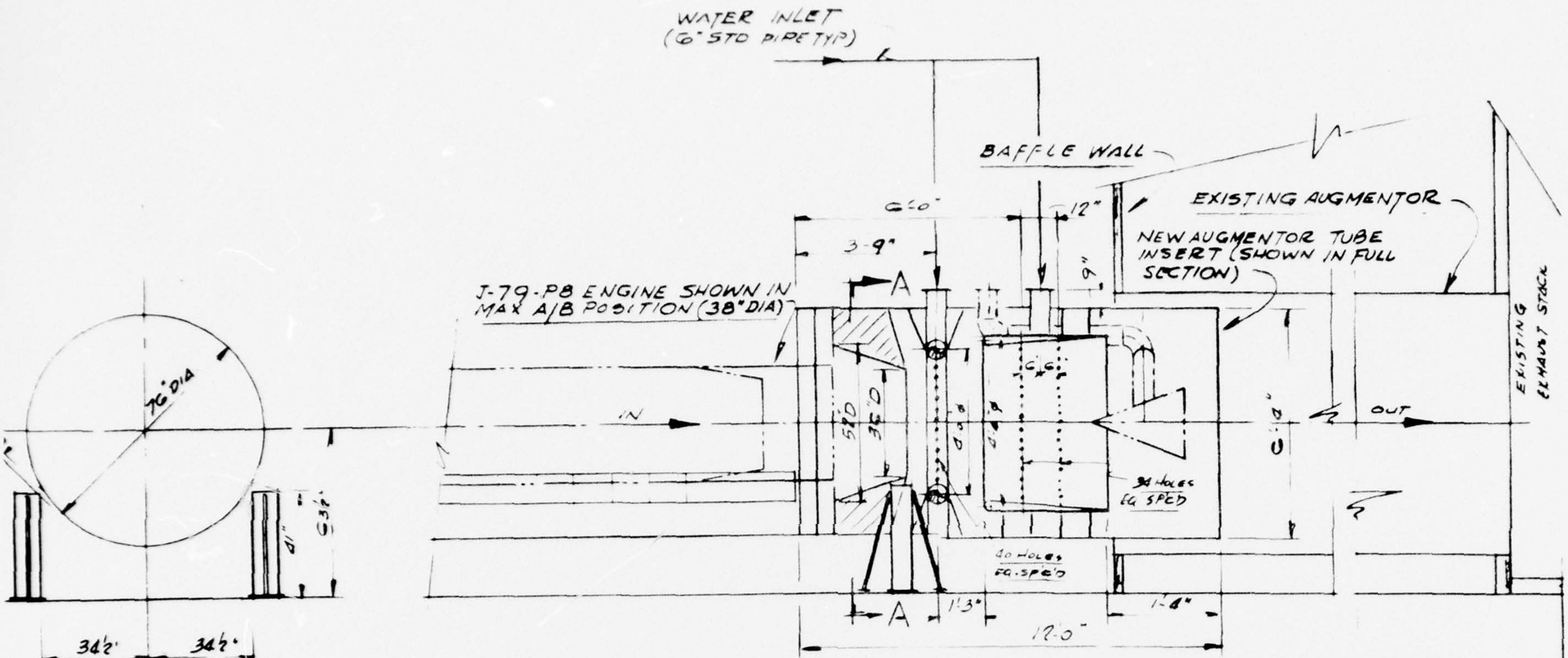
*Static pressure in inches w.g. at the augmenter outlet.

NOTATION: η - Recirculation Ratio

A_a - Augmentation Area Ratio

A_o - Exhaust Area Ratio

ν - Irrigation Ratio



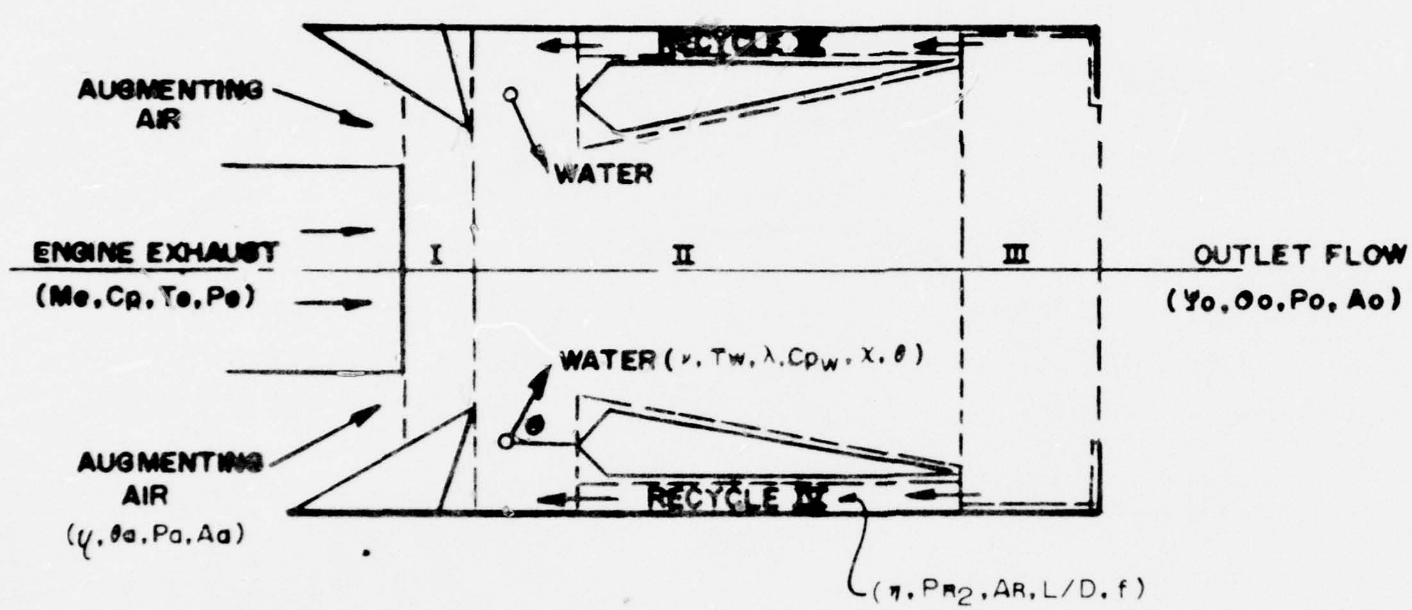
SECTION A-A

SECTIONAL ELEVATION OF EAST BLACK POINT TEST CELL (T.C.#1)

SCALE 1"=30'

FIG. 7-1
P-103-801

BEST AVAILABLE COPY



SCHEMATIC FOR EQUATION DEVELOPMENT

FIG. 7-2

MODEL PREDICTED AUGMENTOR PERFORMANCE AT CONSTANT OUTLET AREA

ENGINE: J-79-8 MAX. A/B

RELATIVE OUTLET AREA, Ao = 5.14

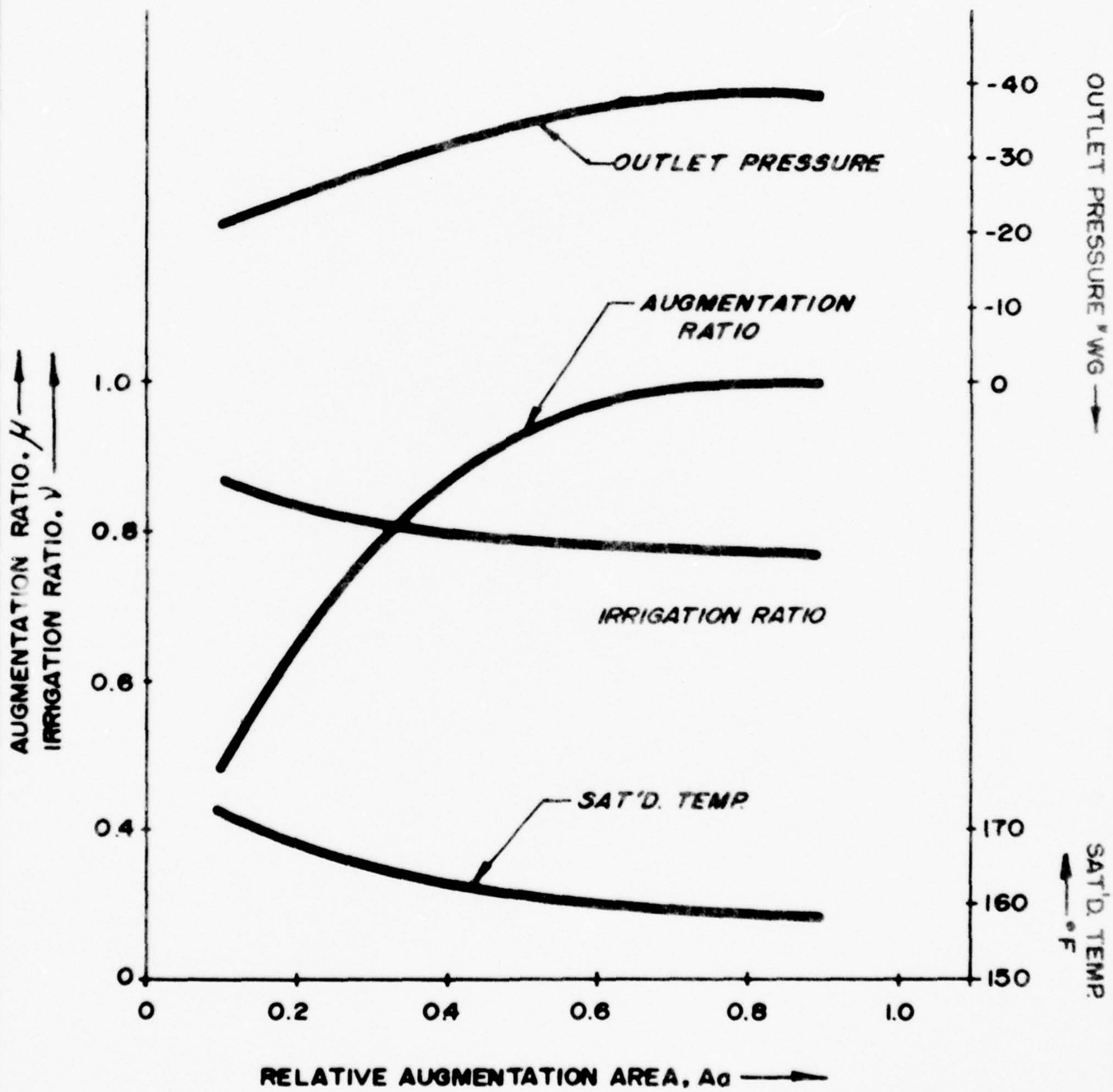


FIG. 7-3

MODEL PREDICTED AUGMENTOR PERFORMANCE AT CONSTANT AUGMENTATION AREA

ENGINE: J-79-8, MAX. A/B

RELATIVE AUGMENTATION AREA Aa = 0.34

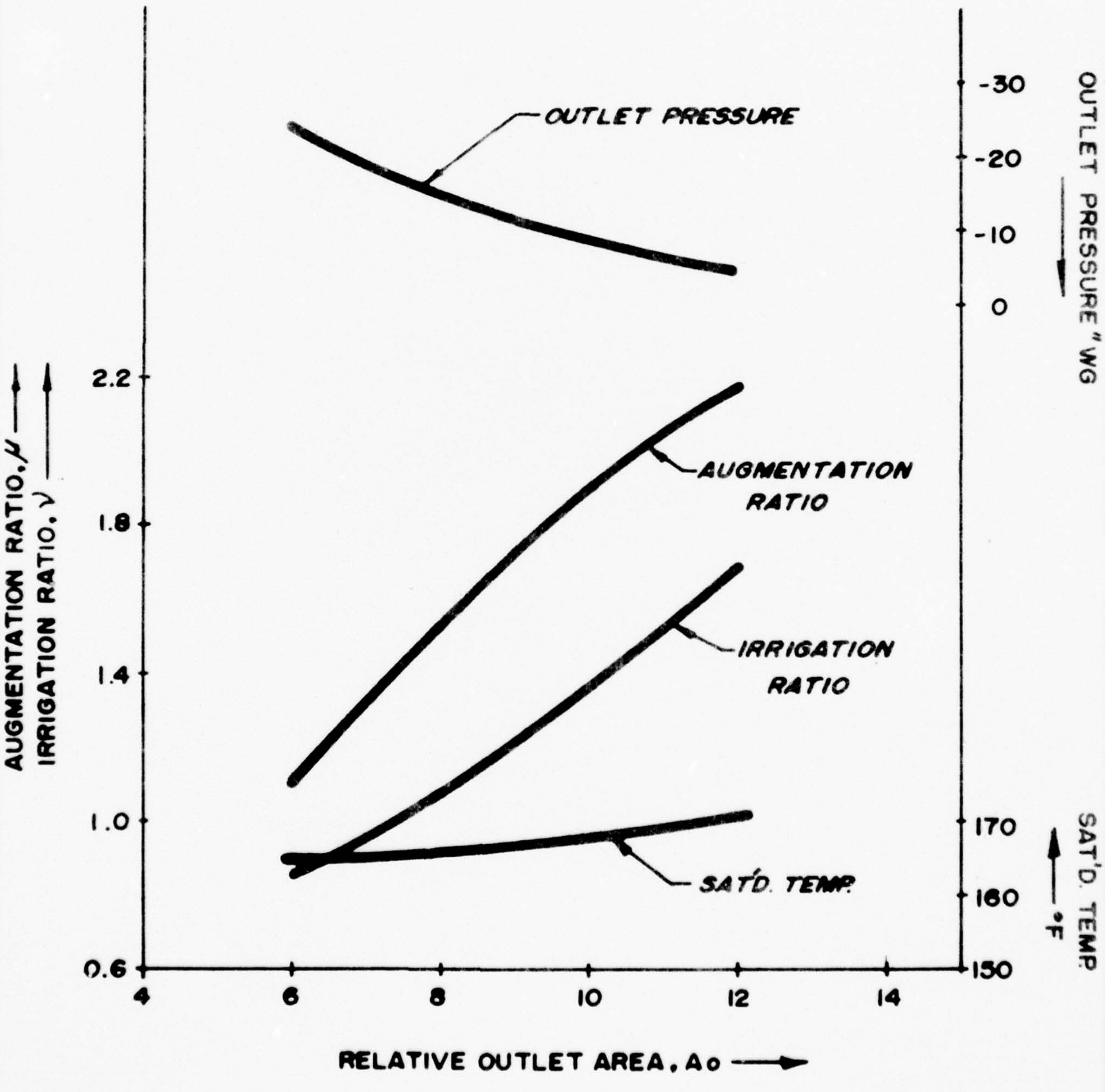


FIG. 7.-4

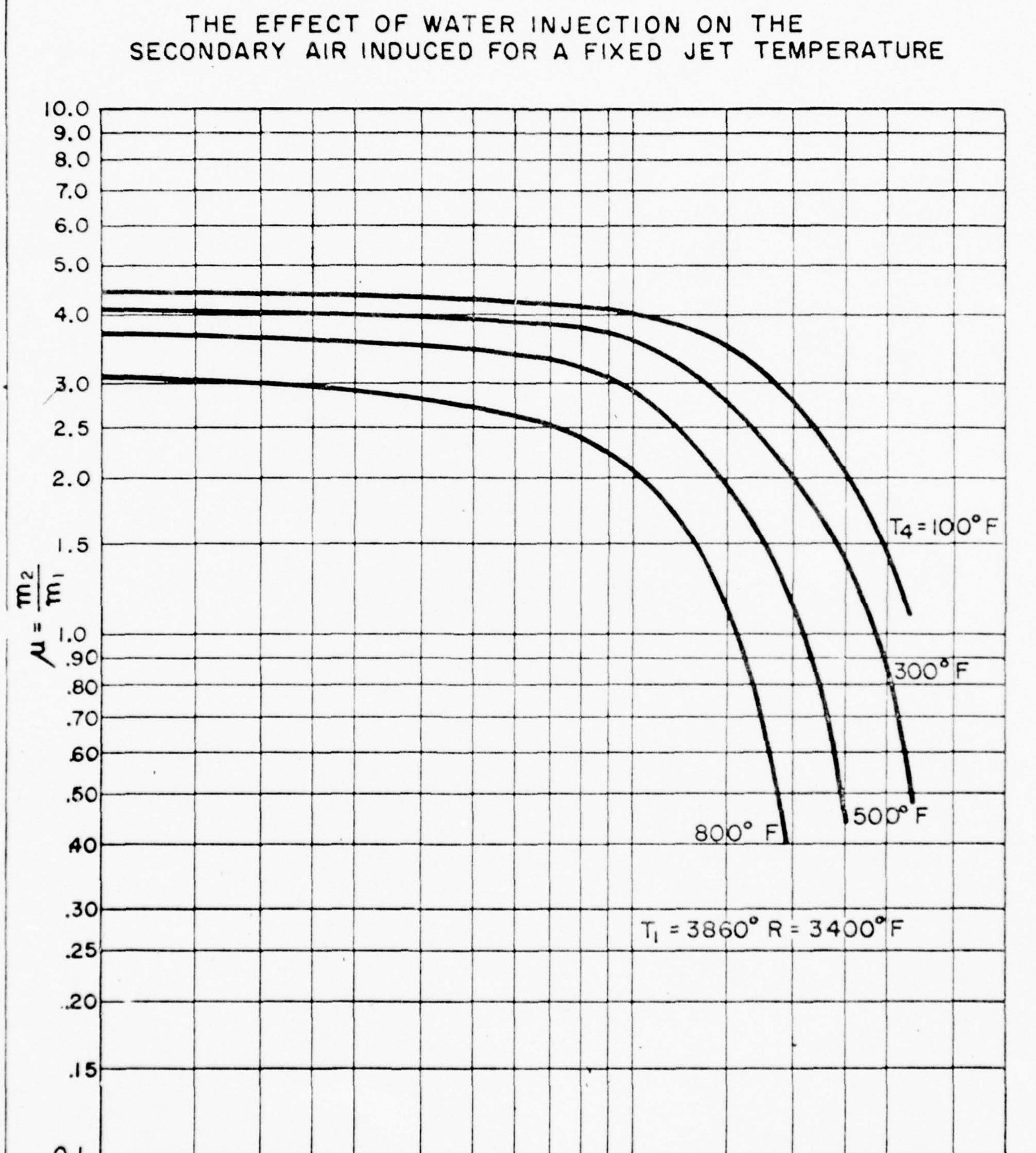

THE EFFECT OF WATER INJECTION ON THE
SECONDARY AIR INDUCED FOR A FIXED JET TEMPERATURE
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
.90
.80
.70
.60
.50
.40
.30
.25
.20
.15
0.1
$\mu = \frac{m_2}{m_1}$
0.1 .15 .2 .25 .3 .4 .5 .6 .7 .8 .9 1.0 1.5 2.0 2.5 3.0 4.0 5.0
$\nu = \frac{m_{H_2O}}{m_1}$
$T_4 = 100°F$
300°F
500°F
800° F
$T_1 = 3860° R = 3400°F$

FIG. 7-5

PERFORMANCE:
Effluent From Engines and Recovery by Scrubber *

8.1 In order to establish the severity of the problem of control of emissions, the quantity, concentration, and particle size distribution of the jet engine emissions were investigated at the exhaust of Jet Test Cell at Black Point, Jacksonville Naval Air Station.

Emission levels were obtained by NARF Chemical Service Laboratories at NAX-NAS and Environment/One. Particle size distribution was established by Environment/One and solids captured by the scrubber were determined by the NARF Chemical Service Laboratories. (Sampling technique by Environment/One is indicated in Appendix 8A).

It should be noted that as a result of severe maldistribution in the gas flow pattern in the exhaust stack of Test Cell 1, the determination of the emission level was difficult. A "core" of high velocity (exceeding 260 fps) occupied approximately 20% of the total stack area (Figure 8-1). The variations in concentrations of particulates in each area sampled are indicated as follows:

(SEE FOLLOWING PAGE FOR TABLE 8-1)

* (Analytical Methods and Procedures - Appendix 8A)

TABLE 8-1

	Point	Mass collected grams	Velocity (fps)	Temperature °F
J-79 Normal	1	.0030	120	400
Time Sampled	2	.0024	230	400
5 min.	3	.0014	60	400
	4	.0019	226	400
	5	.0022	>260	400
	6	.0029	165	400
				(Reported)
Min. AB	1	.0029	130	345
Time Sampled	2	.0038	260	410
4 min.	3	.0022	98	320
	4	.0033	165	410
	5	.0025	>260	320
	6	.0033	184	345
Max. AB	1	.0066	163	375
Time Sampled	2	.0035	>260	375
4 min.	3	.0045	105	375
	4	.0049	165	375
	5	.0066	>260	375
	6	.0053	165	375

8.2 The average emissions established in the tests made are tabulated and compared with the "grain loading" calculated on the basis of the solids collected in the scrubber.

TABLE 8-2

PARTICULATE EMISSIONS FROM JET ENGINES IN TEST CELL

		EMISSIONS - GRAINS/SCF			
ENGINE	MODE	ENV/ONE-1	NARF	ENV/ONE-2(3)	Based on Solids Collected in Scrubber Water,(1,2) (Does not include drain)
J-79	IDLE	0.0092		0.0153	0.0029
	NORMAL			0.0234	0.0131
	MILITARY	0.021	0.0348	0.0388	0.065
	AB	0.059		Questionable	0.08
J-52	IDLE	0.0034		0.0044	
	NORMAL			0.0157	
	MILITARY	0.0059	0.0128	0.0088	0.041
TF-30	IDLE			0.0079	0.006
	NORMAL			0.0079	0.0083
	MILITARY		0.0054	0.0096	0.054

Key:

1 - Gas flow on which loading is based:

J-79	Mil	320,000	scfm	TABLE 7-1
J-79	A/B	260,000	scfm	TABLE 7-1
J-79	Normal	300,000	scfm	Assumed
J-79	Idle	200,000	scfm	Assumed
TF-30	Mil	350,000	scfm	TABLE 7-1
TF-30	Normal	300,000	scfm	Assumed
TF-30	Idle	200,000	scfm	Assumed
J-52	Mil	350,000	scfm	Assumed
J-52	Normal	300,000	scfm	Assumed
	Idle	200,000	scfm	Assumed

2 - Solids collected at base of stack were not measured.

3 - A portion of the particulates were collected prior to this sample because of condensation in the stack and the internal section of the scrubber. This is evident from the total black coating of the internals.

8.2 (Continued)

The effect of high concentration pockets that may not have measured in "averaging" tests in the large cross section stack was raised when data became available regarding the particulates recovered in the scrubber. The solids collected in the scrubber water at military mode ranged from 1.3 to 5.6 times that indicated by the gas effluent tests.

A comparison of particulate loadings obtained from the point gas sampling, those based on solids collected in the scrubber water, and data obtained by other sources are indicated in TABLE 8-3. Although the engines are not the same, they are all turbofans with the JT8D considered "dirty" and the JT9D considered "clean."

TABLE 8-3

COMPARISON OF PARTICULATE LOADINGS FOR TURBOFAN ENGINES BASED ON GAS SAMPLING IN STACK, WATER RECOVERY, AND EXTERNAL DATA SOURCES

	Particulate Loading Grains/SCF			
	From Gas Coll. (Av)	From Scrubber Water and Exhaust Gas	P & W	Northern Research
IDLE	0.0079	0.006 (200,000 scfm)		0.002
NORMAL	0.0079	0.0083 (300,000 scfm)	0.025	
MILITARY	0.0096 0.0054	0.054 (400,000 scfm)	0.022	0.016

8.2 (Continued)

Discussions were held with Pratt and Whitney personnel whose most recent data indicate that inorganics constitute a significant portion of the total emissions, and carbonaceous material loading appears to be low. The major concern, however, is that the capture of the submicron carbonaceous particulates by normal probes may be poor and normal gas analysis of engine emissions may be erroneous. The material captured by the nucleation scrubber may, therefore, be the only realistic measure of engine emissions.

It, therefore, appears that the early data taken at high flows at the stack level was subject to severe error, especially at high flows where maldistribution was evident (Figures 10-1, 10-2, Chapter 10). The particle loading obtained by gas sampling appears to be less at military conditions than indicated by either the engine manufacturer or Northern Research. At this condition, however, the recovered material indicates that the measurements by the engine manufacturers may be low by a factor of 2 to 3.

8.3 The particles recovered from the gas stream with no spray section used in the augmenter were analyzed for particle size distribution (Figures 8-2 to 8-7). It is indicated by population count that approximately 80-90% are less than 1 micron in diameter. Approximately 20-30% by weight are less than 1 micron in diameter. This information is similar to that transmitted by Pratt and Whitney. The Pratt and Whitney study indicated a 0.01-1.0 micron range of particle size with a mean particle size of 0.1 micron.

It was suggested in the initial study (N62467-70-C-0078) that there existed a tendency for agglomeration of the particles. As indicated in the study, "Evidence of the agglomeration tendency indicated in the photomicrographs obtained at Pratt and Whitney Aircraft, where both chain and cluster agglomerates of carbon particles are well identified with chain lengths exceeding 20 particles in many cases."

8.4 Samples of scrubber liquid effluent indicated that agglomeration occurred at various times during recovery in the scrubber. The particles were highly visible and achieved sizes estimated to be in the 5-20 micron range. At other times, no agglomeration was evident and stable suspensions occurred in the scrubber water. The density appears to be lower than that anticipated for carbon. As solid carbon, the specific gravity should be in the range of 1.2-1.8. However, the stability of suspensions almost colloidal in the base, in J-79 operations, implies that the particles, inherently hydrophobic, are coated with JP-5 or degraded JP-5 products, thus lowering the specific gravity to the range of 1.0 to 1.3.

8.5 The quantity of the recovered material is higher than anticipated from gas phase analysis. From measurements taken by NARF (Figure 8-8), it is indicated that as much as 36-44 PPM of undissolved solids accumulated in the scrubber water during military mode for both the J-79 and TF-30. Thus, for a 180 lb/sec engine, the captured solids, formerly depositing as fallout on the community, were accumulated at the rate of 140-170 lb/hr at military mode.

Based on 16 hour operation (Norfolk pattern), the fallout (exclusive of unburned fuel at A/B, part of which goes back in the sump) for a J-79 or TF-30 test is as follows:

TABLE 8-4
PROJECTED FALLOUT FROM ENGINE TEST CELL

	%	Hours	Fallout - lbs* J-79	Fallout - lbs* TF-30
Mil and/or A/B	45	7.2	1260	1040
NR	40	6.4	205	103
Idle	10	1.6	13	6
Turnaround	5	0.8		
TOTAL	100	16.0	1478	1149

*This does not include solids that were collected in the scrubber plenum and dropped into the stack drain. The effluent estimate is, therefore, conservative.

8.5 (Continued)

The fallout from the 11,000 lb thrust engine (exclusive of A/B,part of which appears to have been discharged into the sump) is of the order of 0.6 to 0.75 tons/operating day. Inasmuch as CBC discharge (J-52 CBC) is of the same order of magnitude, the discharge from a 35,000 lb thrust engine could be of the order of 1.9 to 2.4 tons/operating day.

SAMPLING PROBE LOCATIONS

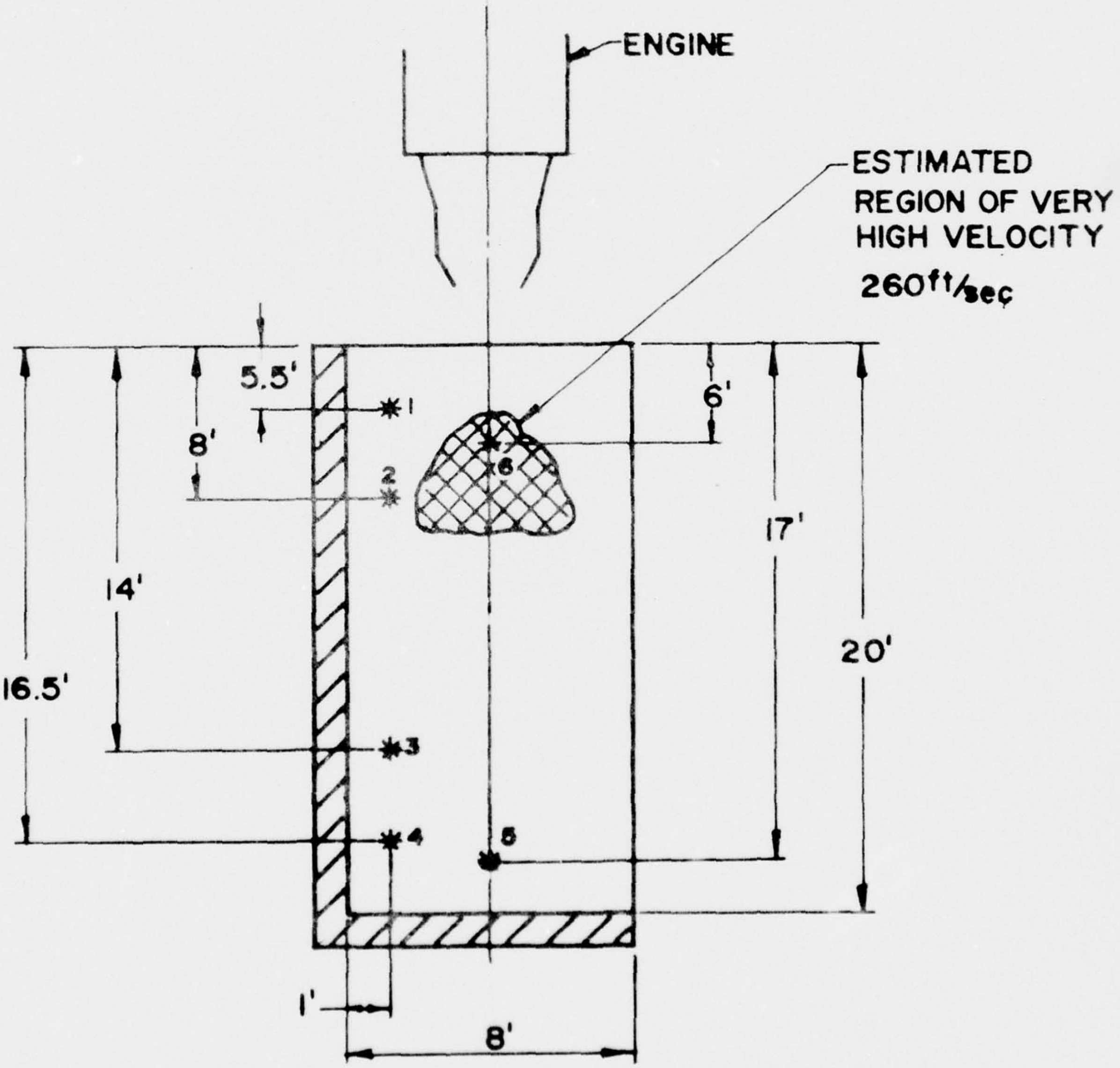


FIG. 8-1

P-103-508

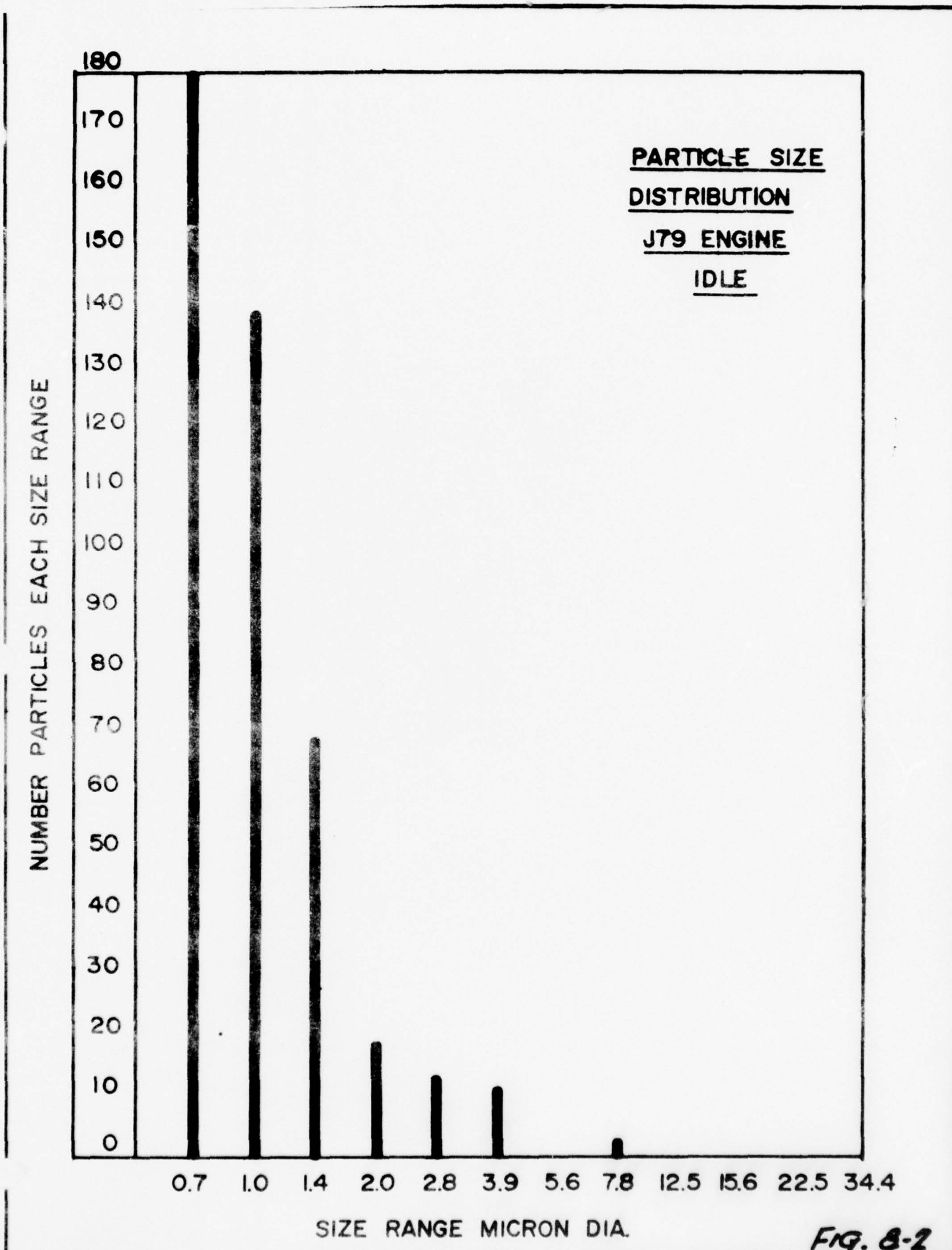


FIG. 8-2

P-103-509

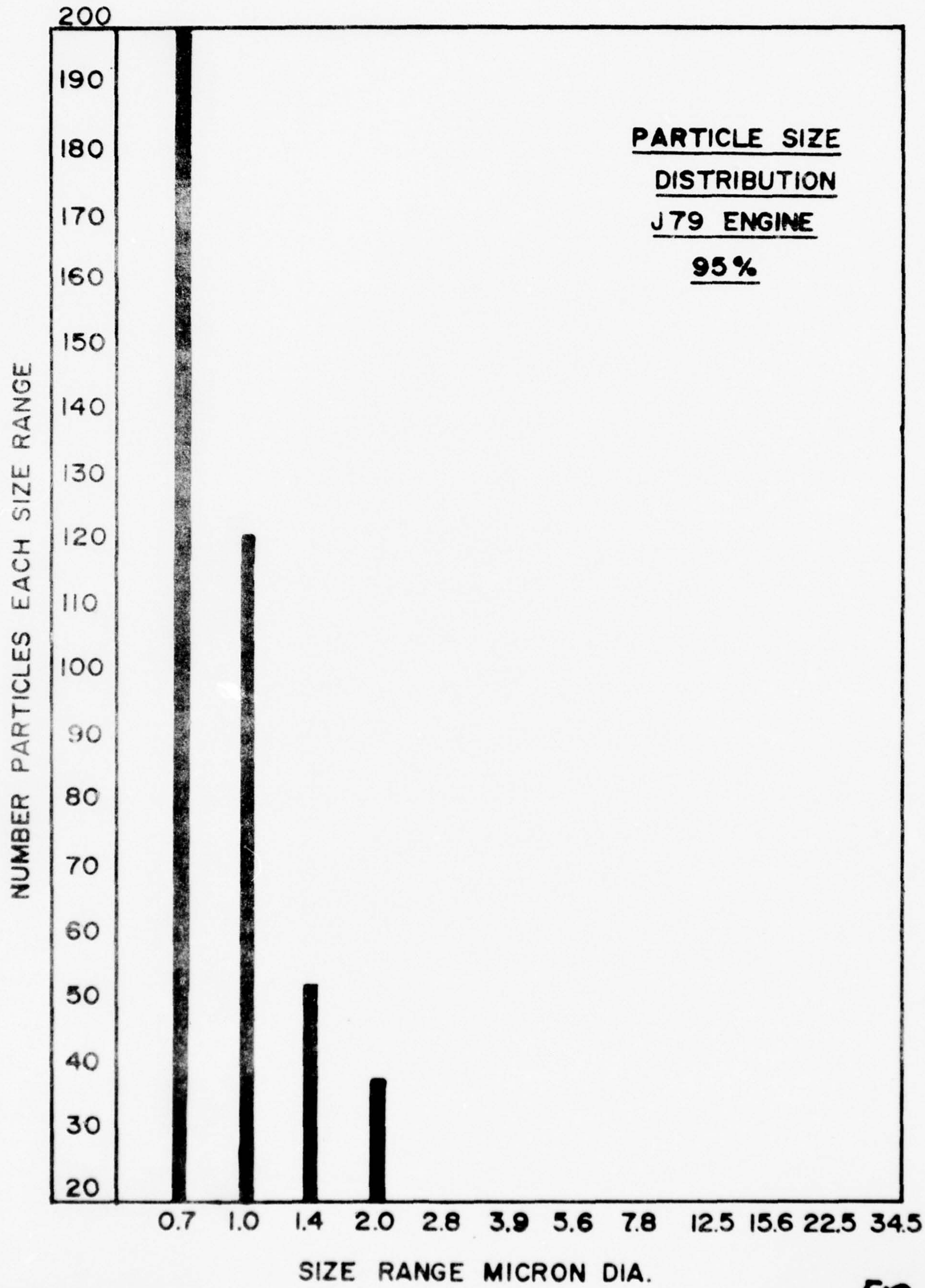


FIG. 8-3

P-103-510

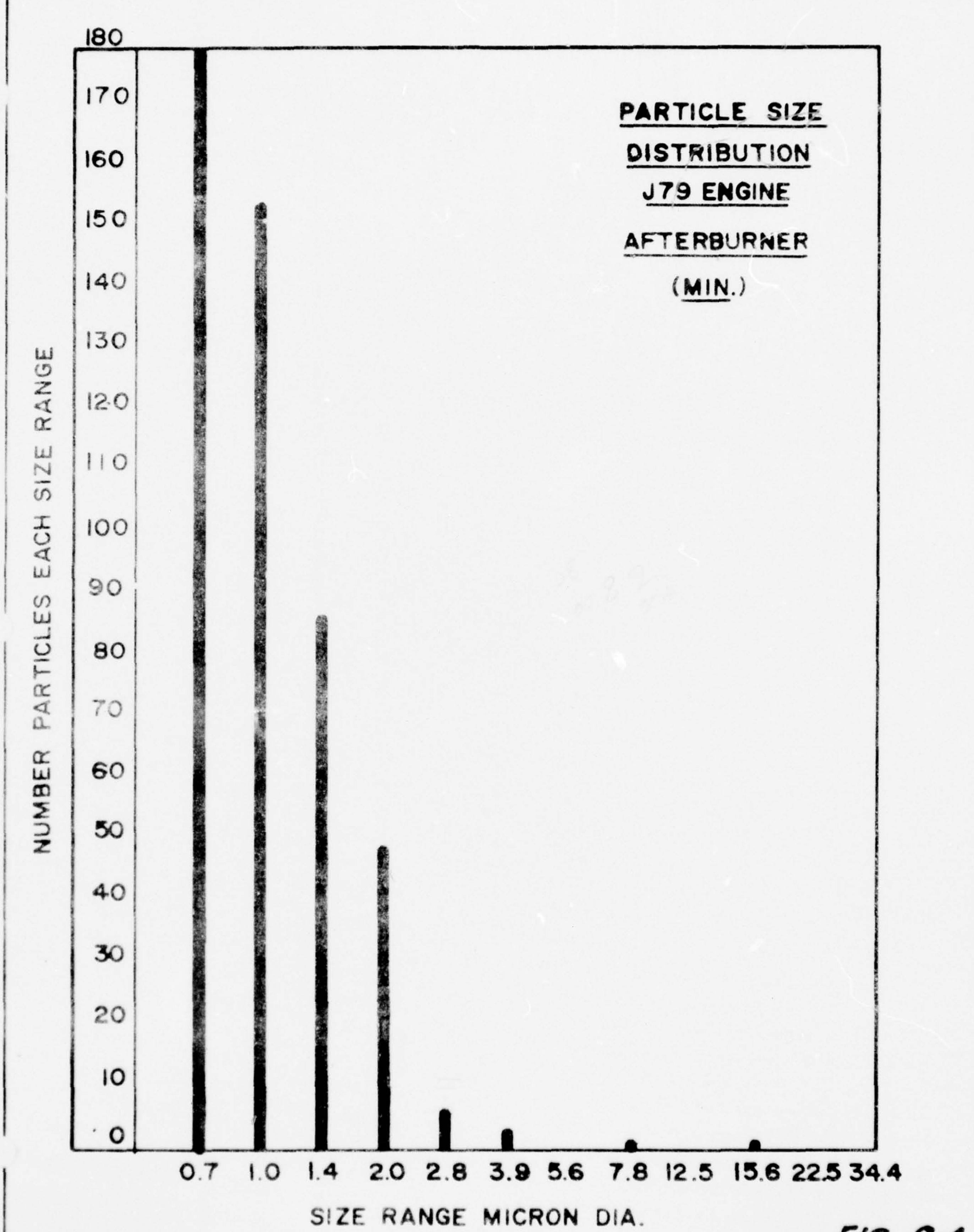


FIG. 8-4

P-103-511

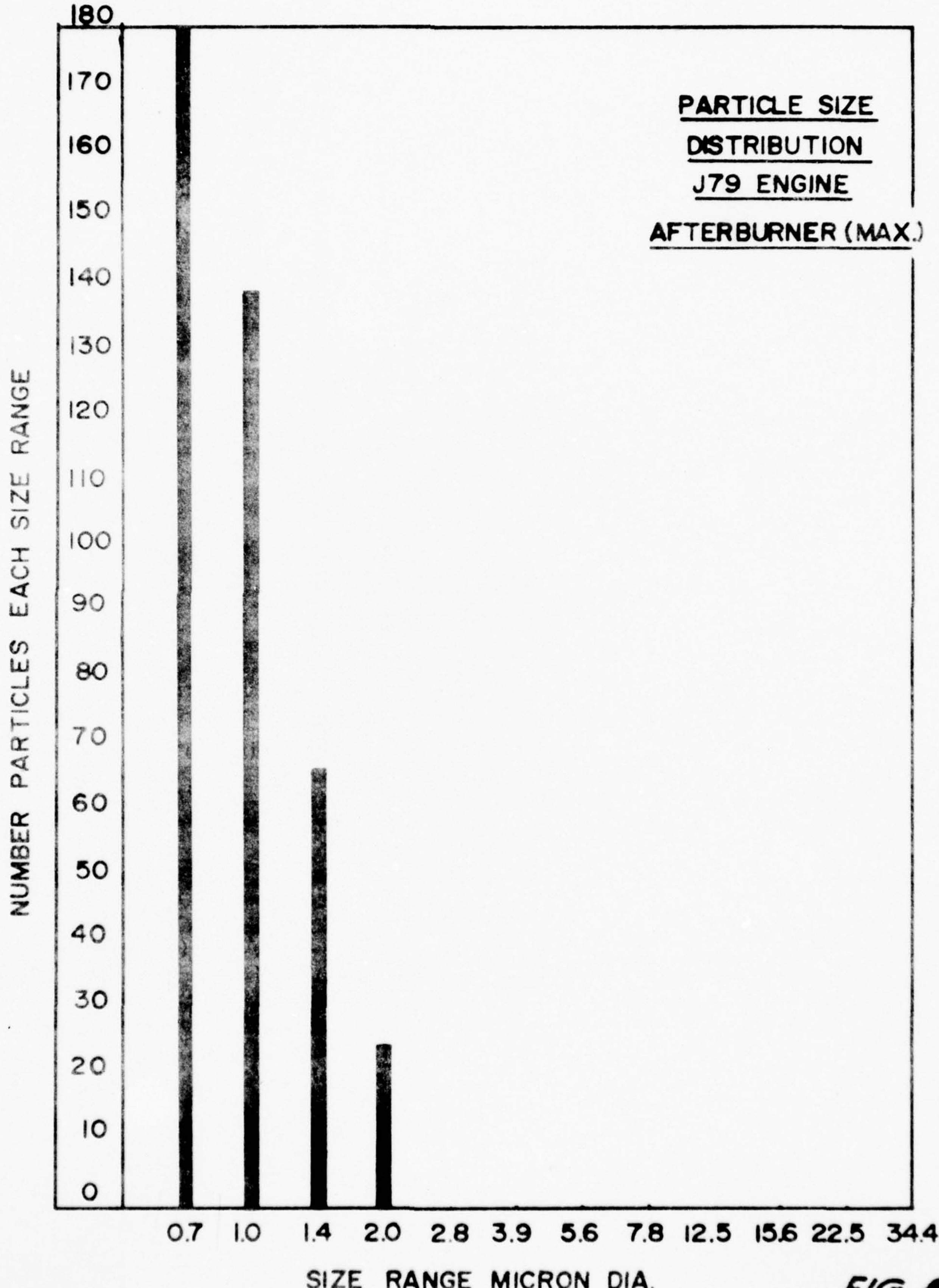


FIG. 8-5

P-103-512

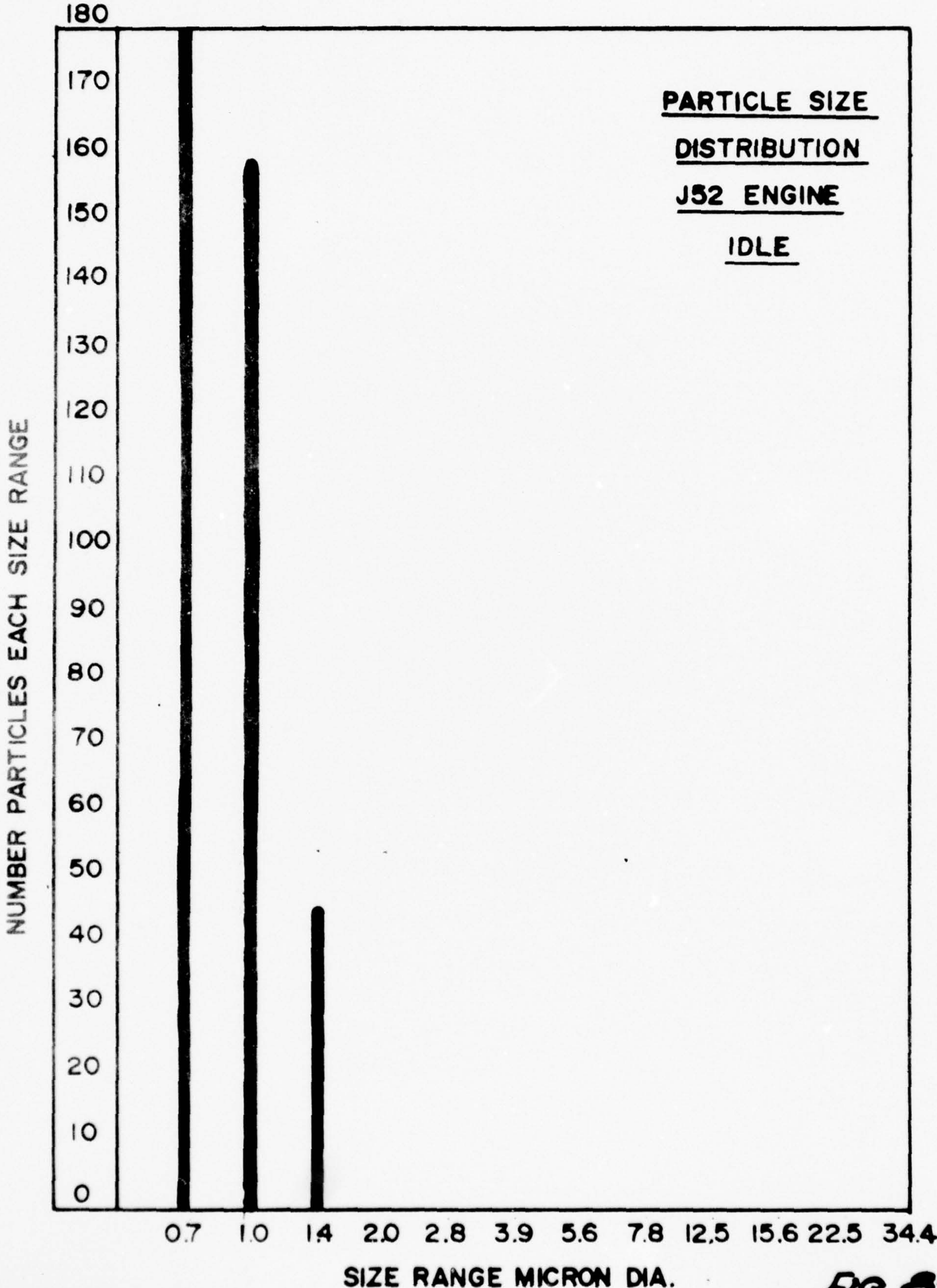


FIG. 8-6

P-103-513

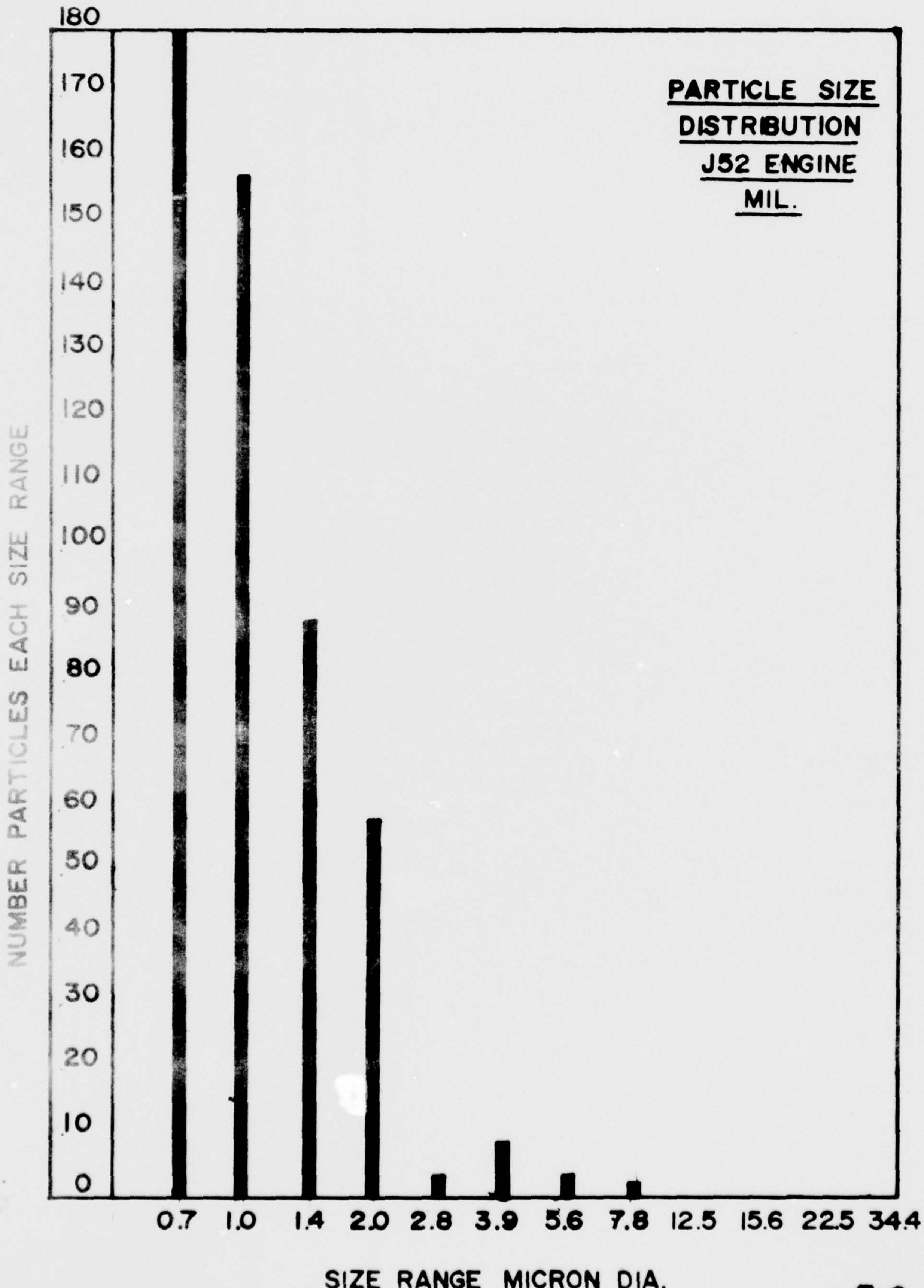
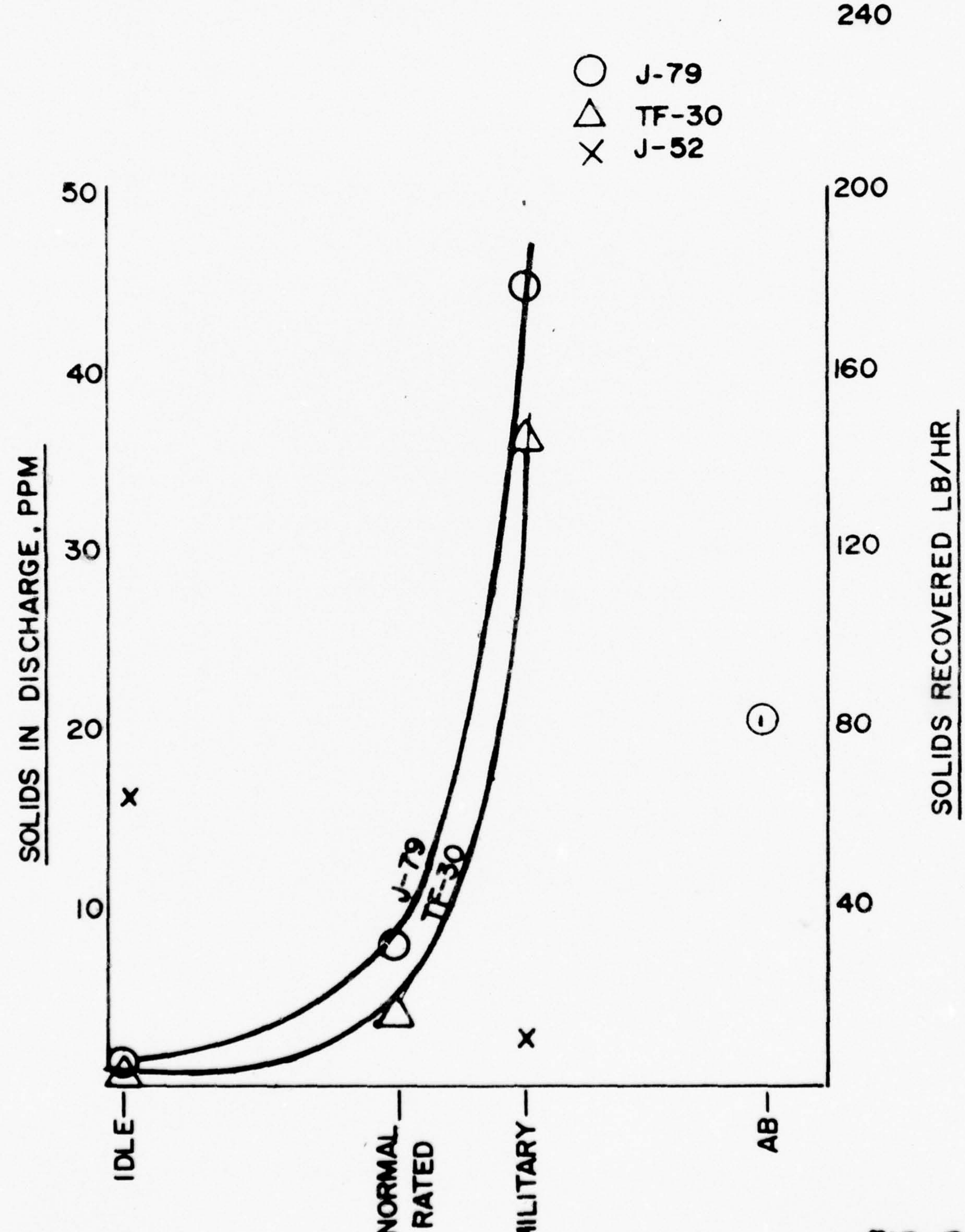


FIG 8-7

P-103-514

RECOVERED PARTICULATES IN SCRUBBER WATER



1- Questionable - Fallout at bottom of stack not measured.

FIG 8-8

P-103-506

PERFORMANCE: TEST Scrubber

9.1 The scrubber was in stable regime over the entire operating ranges of the engines tested. Tests were run with the following engines:

J-79
TF-30
J-52

The scrubber is now on production operation for the J-52 and TF-30.

9.2 Typical run data are indicated in TABLE 9-1, and field data accumulated as a basis for TABLE 9-1 are available in Appendix 9-A.

9.3 In the runs tubulated, the scrubber water flow ranged from 4500 GPM to 8300 GPM, although a series of runs were made by NARF personnel where water flows as low as 1000 GPM were used. The river water temperature, 60°F to 74°F, had no visible effect on the operation or efficiency of the scrubber. The engines were tested in the range of 200 lb to 17000 lb thrust with quench temperatures up to 172°F and effluent temperatures up to an average of 125°F (Calculated by thermal balance).

9.4 The thermal transfer in the scrubber far exceeded the design projection. The design calculations were based on a K_{HA} of 1500. At afterburner conditions for the J-79, outlet water temperature of 130-135°F was predicted whereas the outlet water temperature, under operating conditions, was 168°F. Thus, the thermal transfer was 100% greater than indicated in design. The K_{HA} under the operating conditions was of the order of 3000 - 4000 Btu/(hr) (ft^3) (Btu/lb), based on the reduction in thermal gradient.

TABLE 9-1
PERFORMANCE CHARACTERISTICS
SCRUBBER

Tests	Thrust lbs	Water Flow GPM		Water Temp °F Scrubber		Gas Temp °F		Static Pressure	Thermal Load Million Btu/Hr			Aug. Ratio	Air Flow lb/sec Scrubber			Air Flow ACFM Scrubber		G/A lb/(hr)(ft)²		Discharge Velocity FPS	L lb/(hr)(ft)²	Water Vapor Balance GPM	
		[illegible]	Scrubber	In-let	Out-let	Into Scrub-ber	Ex-haust	In. w.g. = ΔP	Recovered by Liquid	Recovered from Gas	Fuel Cons. Equivalent		Engine & Aug.	In-let	Out-let	Inlet	Outlet	Inlet	Outlet			Evapo-rated	Cond.
[illegible]	[illegible]	50	[illegible]	60	63	81	65	0.1	6.8		2.9										6,100		
	[illegible]	50	[illegible]	60	64	94	64	0.14	9.0												6,100		
	[illegible]	150	[illegible]	60	72	104	65	0.24	27												6,100		
	[illegible]	150	[illegible]	60	80	112	65	0.35	45												6,100		
	[illegible]	150	[illegible]	60	90	122	66	1	67.5												6,100		
	[illegible]	[illegible]	[illegible]	60	92	129	65		110												9,800		
	[illegible]	[illegible]	[illegible]	60	107	137	83	0.3[3]	162	320	169	1.1	373	430	388	415,000	323,000	1,700	1,450	5.4	9,800	378	310
	[illegible]	[illegible]	[illegible]	60	144	153	104		311	203		0.8	296	390	310	410,000	296,000	1,620	1,230	5.0	10,700	430	330
	[illegible]	[illegible]	[illegible]	60	168	172	160[1]		437	204[1]	592	0.60	288	425	374	450,000	400,000[1]	1,520	1,630[1]	6.7[1]	11,300	972	350[1]
							126[2]		437	437[2]	592		288	425	318		292,000[2]		1,230[2]	4.9[2]	11,300	972	768[2]
[illegible]	[illegible]	[illegible]	[illegible]	64	ND	115															11,700		
	[illegible]	[illegible]	[illegible]	64	ND	113/126	70														11,700		
	[illegible]	[illegible]	[illegible]	64	ND	136	78/103				169										11,700		
	[illegible]	1,100	[illegible]	64	ND	172	157[1]			210[1]	592		288	425	365	380,000	373,000[1]	1,820	1,510[1]	6.2[1]	11,700	972	412[1]
							125[2]		437	437[2]	592		288	425			292,000[2]		1,230[2]	4.9[2]	11,700	972	768[2]
[illegible]	[illegible]	100	[illegible]	73	75	93	80		8												11,100		
	[illegible]	100	[illegible]	74	76	97	74		8												11,100		
	[illegible]	100	8,000	74	90	114	76		64												11,100		
	[illegible]	700	8,000	74	94	116	76		80												11,100		
	[illegible]	700	[illegible]	74	105	125	76	1.06[3]	124	152	149	0.6	432	472	440	440,000	358,000	1,830	1,610	6.0	11,100	296	235

1 - Outlet Gas Temperatures were taken at south end of scrubber before restrictive baffles were installed. Thus, this was the area of maximum gas flow indicating excessively high temperatures.

2 - Outlet Gas Temperatures were calculated based on thermal pick-up by liquid.

3 - Reported data are by Environment/One.

ND - No Data

RAW DATA IN APPENDIX [illegible]

9.4 (Continued)

The Scrubber responded to the thermal demand of the gas stream. Based on the thermal pick-up by the water, in excess of 85% of the energy of combustion was recovered up to and including military mode at maximum afterburner (TABLE 9-1). For example, for the J-79 in military mode, the thermal pick-up was 162 x 10^6 Btu/hr, whereas the thermal value of the fuel burned was 169 x 10^6 Btu/hr. In the case of the TF-30, 124 x 10^6 Btu was absorbed by the water while the fuel value was 149 x 106 Btu/hr. The thermal value of the fuel burned was 592 x 10^6 Btu/hr.

The relationship of heat absorbed by the scrubber and temperature of exhaust gas with thrust is indicated in Figure 9-1. The temperature of the scrubber exhaust is constant up to a thermal load of 100,000,000 Btu/hr. Beyond this, the exhaust aas temperature rose to a calculated maximum of 125°F (average) at afterburner mode, at a thermal load of 437,000,000 Btu/hr. The observed effluent gas temperature at the bottom of the scrubber at the south end of the scrubber was measured to be 150°F to 160°F. The behavior of the cross flow mechanism would project a gas temperature in the range of 135°F to 150°F at this effluent point. The deviation is believed to have been caused by severe maldistribution of gas effluent in the test cell stack with the majority of the gas flowing through the south end of the stack. An implied confirmation of this phenomenon is indicated in the visual observations section - (9.9.2), wherein baffles placed in the stack to minimize the maldistribution were found to have been subjected to velocities in the 300 ft/sec range although the "average" velocity should be in the 50 ft/sec range.

9.5 The pressure drop through the scrubber was originally estimated in design to achieve a maximum of 4-6 in.w.g. during afterburner operation. Measurement of the static pressure inside the scrubber, equal to the pressure drop through the packed section, was complicated by the consensation of water in the transfer lines to the manometer,

9.5 (Continued)

especially in military and afterburner modes. Readings as high as 12 in.w.g. were recorded but were questionable because of condensation in the lead lines. In the case of the J-79 engine test, reliable readings up to 1 in.w.g. were measured up to a thrust of 6000 lb. Subsequent tests made by military conditions for the J-79 and TF-30 were "averaged" by manifolding the probes at 6 points along the length of the scrubber with lead lines at the same level of the probes. At military, the pressure drop through the scrubber was found to range from 0.8 in.w.g. to 1.1 in.w.g. for both the J-79 and TF-30.

9.6 The gas flow through the scrubber was calculated by the application of augmentation data obtained by NARF personnel prior to installation of the scrubber. One test made subsequent to the installation indicates a reduction in augmentation for the TF-30 in military mode from 0.6 to 0.39. This would represent a 12% reduction in flow as estimated in TABLE 7-1. Inasmuch as augmentation data were only acquired by NARF for military and afterburner modes, analysis of flows were calculated for these conditions.

As a result of installation of the new augmentor, flows were substantially reduced from that occuring with conventional augmentor design. The study of effect on gas flows by the TESI augmentor is indicated in Chapter 5. The effect of reduced augmentation flow resulted in the decrease in pressure drop in the scrubber and a reduction in the correction gas flow G/Φ in lb/(hr) (ft^2) from 2,260 projected to 1,830 actual, a decrease of 19% in mass load. The gas flows in lb/sec at augmentation levels measured by NARF are indicated in TABLE 9-1.

The gas flows to the scrubber from the stack ranged from 440,000 to 480,000 ACFM at maximum demand conditions and gas emission from the scrubber ranged up to 358,000 ACFM, the maximum occurring at TF-30, military mode. Although there appears to be a maximum of 400,000 ACFM exhaust at J-79 AB mode, this is believed to be incorrect because of effluent temperatures at the maldistribution maximum flow

9.6 (Continued)

point and at the lower section of the scrubber. As indicated in Section 9-4, the calculated average effluent gas temperature at these conditions is 125°F rather than the 150°F - 160°F measured and that the effluent flow is of the order of 290,000 ACFM.

Operating conditions for the scrubber, therefore, indicate that the maximum gas flows are equivalent to a corrected mass flow of G/Φ = 1,830 at inlet and 1,610 at outlet, both values well within the capacity of the TESI scrubber.

The velocity of the effluent gas from the scrubber ranged up to approximately 6 fps average at maximum operating conditions.

9.7 The water flow to the scrubber ranged up to 8,300 GPM. Twenty-five percent of this flow was diverted to face sprays in order to protect the packing and support grids from "hot spotting." The remainder (75-80%) of flow was used for irrigation of the packing. The irrigation of the packing was thus 11,700 lb/(hr) (ft^2) at maximum conditions.

Stable liquid flow operation occurred except for TF-30 military and J-79 afterburner conditions. During these operating conditions, considerable overflow occurred from the sides of the water sump. The phenomenon is reflective of an inadequacy of the approach angle of the packed section and maldistribution of gas flow. The angle of the packed face to the vertical is 4°46' with a lateral displacement of the bottom of the face to the top of the face of 1.33 ft. Observation of side overflow indicates that the water exits from the

9.7 (Continued)

outside face at a level of 2'-3' above the bottom support plate. Thus, the lateral displacement should have been 2'6" rather than 1'4" with the angle of attack of 9°.

9.8 Evaluation was made of the water balance in the system. The basis for the evaluation was the water content of the gas entering the scrubber (quench water evaporation) and the water content of the gas leaving the scrubber. The difference is the make-up water required for scrubber operation (TABLE 9-2), and does not include the cooling tower losses. The make-up losses were as follows:

TABLE 9-2

Loss of Fresh Water in Augmentor-Scrubber Operation

	Water Net Loss GPM	Percent of Quench Requirements	Percent Recovery of Quench Water
J-79 Mil	68	18	82
J-79 Min AB	100	23	77
J-79 Max AB[1]	204	21	79
TF-30 Mil	61	21	79

[1] Calculated from Thermal Balance

9.9 APPEARANCE AFTER OPERATION

9.9.1 Inspection of the scrubber subsequent to the initial runs indicated no deterioration of components. The packing facing the stack exhaust section had a coating

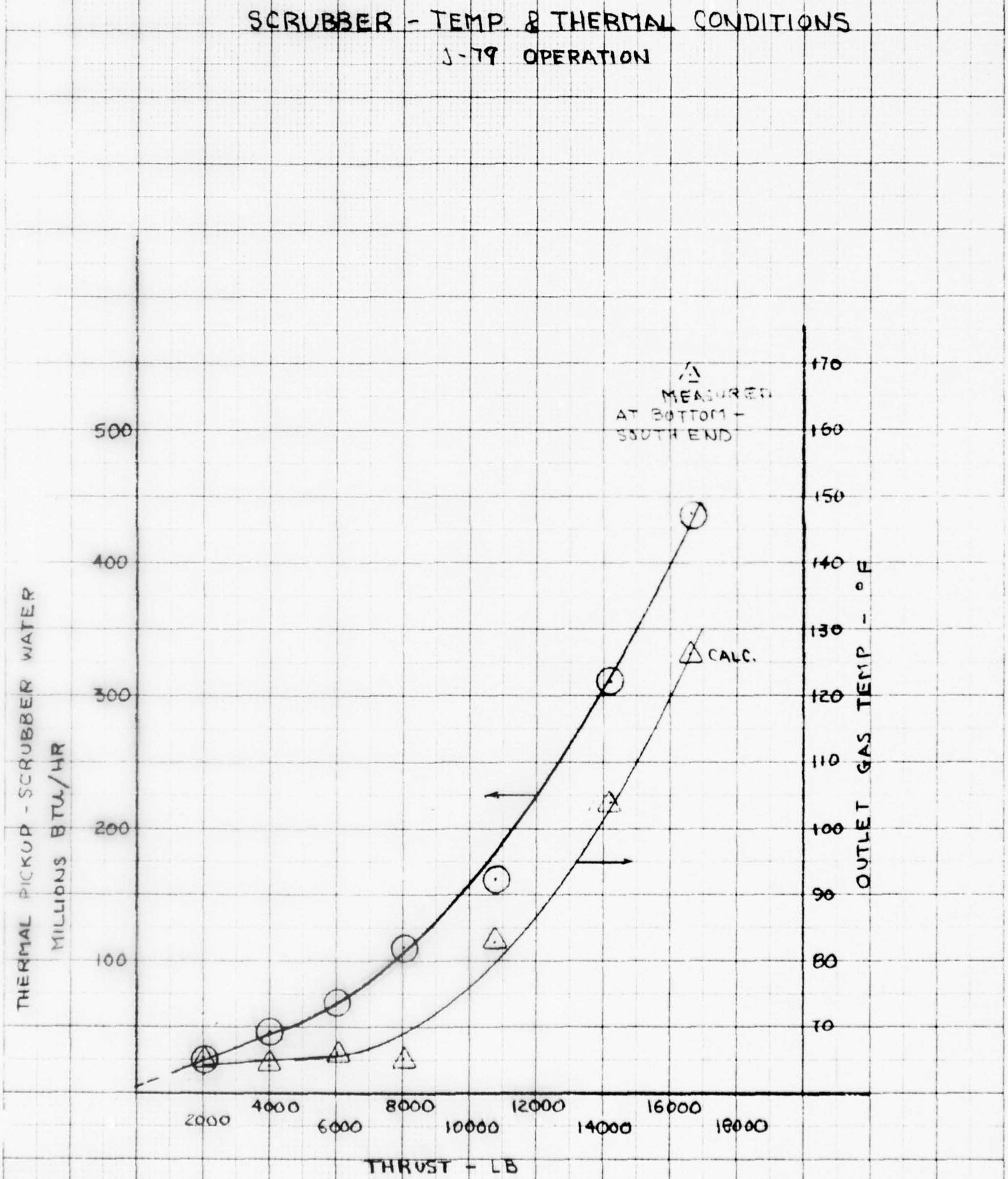

SCRUBBER - TEMP. & THERMAL CONDITIONS
J-79 OPERATION
THERMAL PICKUP - SCRUBBER WATER
MILLIONS BTU/HR
OUTLET GAS TEMP - °F
THRUST - LB
MEASURED AT BOTTOM - SOUTH END
CALC.
500
400
300
200
100
170
160
150
140
130
120
110
100
90
80
70
2000
4000
6000
8000
10000
12000
14000
16000
18000

FIG 9-1

9.9.1 (Continued)

of carbon and appeared more translucent than when originally placed in the scrubber. It was noted that both the grating and the packing on the south end of the scrubber were darker than the sections at the north end, indicating maldistribution in the scrubber with higher flows occurring at the south end.

9.9.2 Pipe baffles were installed at the south end at the top of the stack in order to redistribute the flows (Figure 5-2). Initially, some of these baffles were ripped from the stainless steel bolts indicating that they were exposed to velocities far in excess of that projected in design.

[With a flow of 500,000 ACFM after quench, the "average" velocity in the 160 ft^2 stack would be 52 ft/sec. Consideration of the sound attenuation units occupying 50% of the cross section and assuming that no expansion occurs subsequent to passage through the sound attenuation units, the "average" velocity would be 104 ft/sec. Inspection of the baffles indicate 90° bends in 1/4 inch bolts and tearing of 1/4" thick FRP walls. The force estimated to achieve this phenomenon is of the order of 50 to 100 lbs. For a 4 foot long piece of pipe, this is equivalent to 50 to 100 lb/ft^2 with full head conversion. The velocity required to produce this force, if fully converted to a head loss, would be of the magnitude of 300 FPS].

9.9.3 Although the shell was originally light green, the roof and side wall areas between the packed zone and the stack were coated with carbon deposition after three engine runs. The remainder of the shell and gull wings were only slightly dirty after 2 months of operation.

9.10 APPEARANCE DURING OPERATION

9.10.1 During operation up to thrusts of 8000 lbs, the stack emission was wispy with a very low exhaust velocity appearance. At military mode, the quantity of steam in the exhaust projected as much as 20 feet. In the case of the TF-30 during military mode, water flowed from the lower sections of both sides of the scrubber to a height ranging from 1 to 2 feet. In the case of the J-79, this phenomenon was evident only during afterburner regime.

During the afterburner operation, the steam plume pervaded as much as 300 feet before it dissipated. Traces of residual were observable but not on a consistent basis. The residual was light yellow in color.

SCRUBBER - TEMP. & THERMAL CONDITIONS

J79 OPERATION

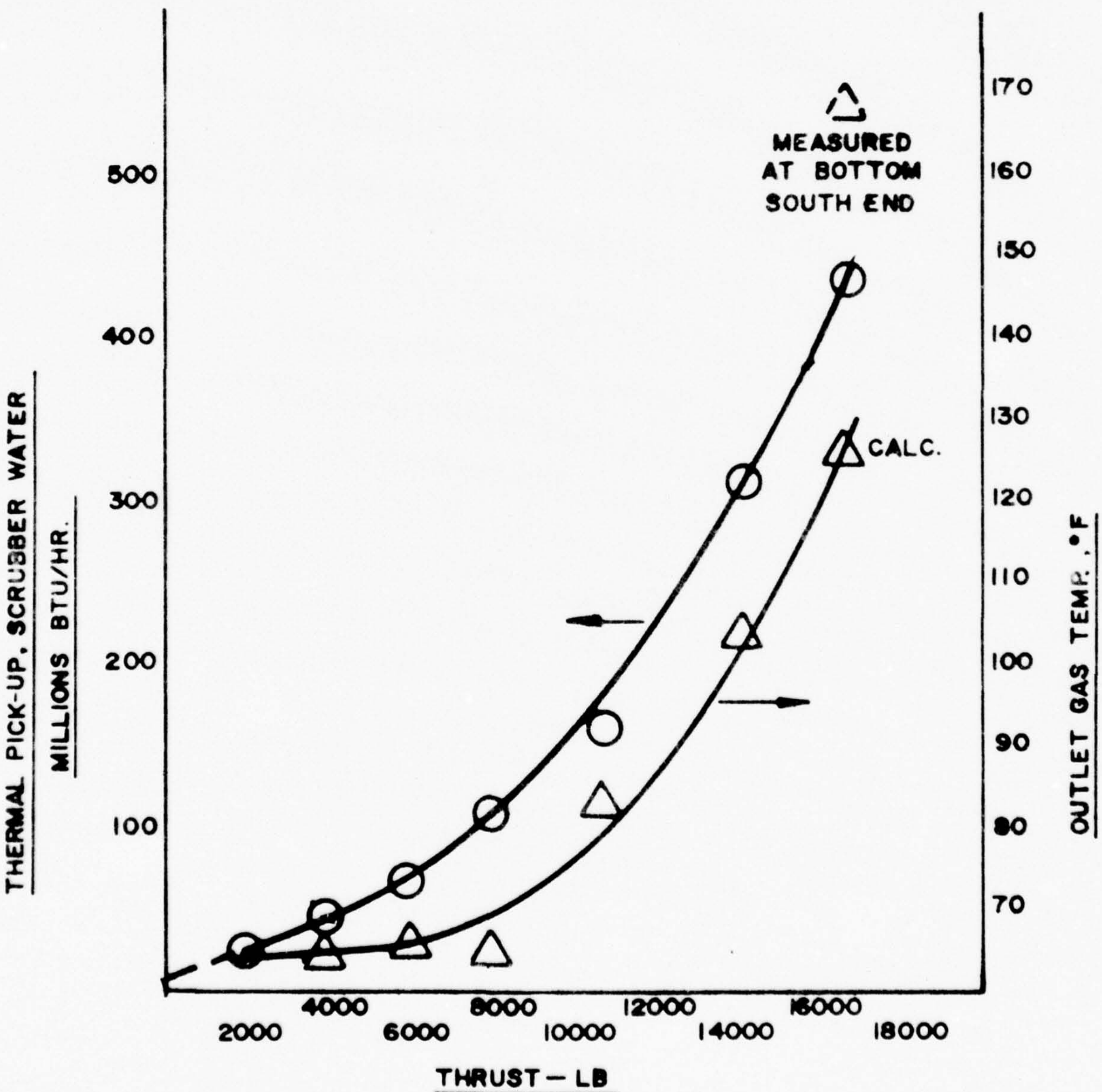


FIG. 9-1

P-103-505

PERFORMANCE: Augmenter

10.1 VISUAL:

The performance of the augmenter with air scoop removed was observed by both Navy and TESI personnel. The maximum system demand occurred during test of the J-79 in A/B. It was observed that the jet exhaust flame appeared to fill the entire venturi throat. The first spray ring that appeared to penetrate the jet completely at lower engine rate bent into the jet at a diameter of approximately 1-1/2 feet at military rates. The recycle phenomenon was quite pronounced at A/B operation. It blended with the jet at the trailing edge of the converging section of the venturi, and water droplet recycle was observable.

The residual core of the jet exhaust subsequent to the primary spray appeared to be 6" to 12" in diameter. Thus it should have dissipated in 5 feet to 9 feet. Inasmuch as the distance traversed to the core buster was only 4 feet, residual jet core existed at this position.

10.2 MECHANICAL:

The augmenter system did not appear to be overstressed. No shell or internal vibrations were noticeable.

Failure did occur on the core buster supporting struts because of incomplete dissipation of the jet core and lack of protection of the struts. The hot zone was approximately 2 inches wide at the failure area, indicating that the residual core at this point was approximately 6 inches in diameter and would dissipate in approximately 4-1/2 feet.

10.3 THERMAL:

No thermal damage was visible to any portion of the augmenter. Some discoloration was noted at the venturi throat and appeared to be caused by radiation rather than convection.

10.4 MEASUREMENTS:

Performance data were obtained by Navy personnel with the following engines:

J-52
J-79 Through A/B
TF-30

Data were obtained as follows:

1 - Water consumption

2 - Augmentation

3 - Temperature profiles in stack

4 - Velocity profiles in stack

10.4.1 WATER CONSUMPTION

The limiting test for water consumption was based on the J-79 in A/B mode. Based on fuel consumption and total enthalpy (thermal + kinetic equivalent), the exhaust jet enthalpy is of the order of 170,000 Btu/sec.

The contribution of the enthalpy of augmentation air is relatively low.

Augmentation Ratio	Thermal Contribution to the Exhaust Btu/sec
0.5	1575
1.0	3150
2.0	6300
3.0	9450

10.4.1 WATER CONSUMPTION (Continued)

The quench water feed rate provided for this maximum duty was calculated to be 950 GPM. Design for the system was established at 650 GPM for the primary ring quench and 500 GPM for secondary quench, either at the diverging zone of the venturi or at the core buster.

No significant data were obtained with regard to secondary quench until pump adjustments were made. Burnout of the core buster vanes occurred prior to pump correction.

10.4.2 AUGMENTATION

The degree of external augmentation in one physical orientation of the TEST augmenter is compared with those values obtained with the previously used 48"D and 72" forcing cone augmenter. The data on the conventional augmenter were obtained by NARF. The data on the TEST augmenter were obtained and supplied by NARF with TESI personnel present in some of the runs.

The reductions in augmentation achieved with the TEST augmenter were:

TABLE 10-1

REDUCTION IN AUGMENTATION

Augmentation Ratio		∿ Percent	
Initial	Final	Reduction	Remarks
1.9	0.64	67% for the J-79 in A/B	Where 48"D forcing cone was used in old augmenter
1.21	0.62	50% for the TF-30 in MIL	
1.9	1.33	30% for the J-52 in MIL	
2.12	0.38	82% for the TF-30 in MIL	Where 72"D forcing cone was used in old augmenter and 30" throat was used in the TESI unit.

10.4.2 (Continued)

The differences in effect are ascribed to the change in the ratio of the augmentation area to the exhaust area (TABLE 7-3). A proposed solution is to have a variable throat diameter. However, this was not necessary in the Black Point installation inasmuch as the limiting factors in the design of the scrubber system were the largest engine and the flows related to its performance, and the minimum temperature of the combined stream of jet exhaust and augmentation air. Both were adequate.

Data submitted verbally by NARF indicated that the recycle velocity in the annulus is 100 fps. If this flow returned to the vena contracta of the venturi, it would create an internal augmentation of approximately 0.6. As a result, the total gaseous augmentation in the J-79 would be of the order of 1.1 to 1.2. However, with recycle blanked off, no significant change in external augmentation was observed indicating that no significant recycle returned to the vena contracta.

The bounce spray effect projected and described in the initial study (Contract No. N62467-70-C-0078, pp. 20-21) was observed to operate via entrainment carry of the recycle gas into the throat of the venturi arrangement. It is believed that this phenomenon contributed to the reduction in augmentation air flow.

It is possible, based on the experience gained in the test program, that further reduction in augmentation may be achieved by:

1 - Arranging recycle air flow into the venturi throat;

2 - Decreasing the recycle scoop-baffle diameter with effect of increasing the recycle augmentation;

3 - Injecting water directly into the recycle annulus to increase the quantity of bounce spray-flash.

It should be noted that mere addition of water to

10.4.2 (Continued)

the spray section will not, in itself, decrease augmentation significantly. This can be observed in TABLE 5-3 where water injection was used in the TF-30 and the J-79 military regime. These tests, run to confirm the mathematical model submitted in the preliminary study, indicated a reduction in augmentation of only 8.5% for the TF-30 and zero for the J-79. For water to decrease augmentation, it must be fed at the throat. The recycle mechanism can achieve this with minimum possibility of water contact with the engine.

10.4.3 TEMPERATURE PROFILE - VELOCITY PROFILE

The data taken for the TF-30 and J-79 regarding temperature and velocity distribution from the stack are plotted in Figures 10-1 and 10-2. In the case of the TF-30, the temperature and velocity profiles are consistent for the three latitudinal bands and apparently follow a distribution established by the four baffles at the bottom of the stack. The first baffle requires too high an angle of turn and is located too high to critically affect flow. The point temperatures apparently are related to the point velocities and the baffle position. Temperatures decrease with velocity within a specific baffle position (Figure 10-1) and in a direct relationship in positions 1-8, but in a totally different direct relationship in positions 9 and 10 (Figure 10-2). These plots indicate the temperature maldistribution may not at all be related to the mixing in the augmenter but the mode of temperature measurement.

In the case of the J-79 data (Figure 10-2), the spread of the data is far greater than that observed for the TF-30. Again, the anomalous behavior at positions 9 and 10 are evident. An inverse type of relationship of temperature and velocity occur in positions 1-5. However, the scatter of both velocity and temperature is too great to provide any pattern at positions 6-8.

The plot of temperature vs. velocity represents only latitude A. The anomaly of positions 9 and 10 are

10.4.3 (Continued)

are, again, quite evident. But except for one and possibly two points, a relationship of temperature and velocity appears to exist.

This relationship of temperature and velocity may result from the existence of entrained water. The gases are highly humidified, but not uniformly, and the temperature recorded may be a form of wet bulb that is highly responsive to velocity, and not reflective of the true temperature of the stream. It is evident in these profiles that modification of the existing baffles be undertaken in order to preclude the anomalous behavior at positions 9 and 10 and to minimize variation in flow.

It was noted by NARF-JAX that during maximum A/B mode in J-79 test, a temperature greater than 1800°F was measured at the axis downstream of the TESI augmenter. Based on temperatures measured at various radial distances, it was estimated that the core is a maximum of 6" in diameter and, therefore, represents between 5% and 15% of the flow. Dissipation of this core before the baffle section must predominate because of the normal breakup mechanism.

10.4.4 ENGINE STATUS

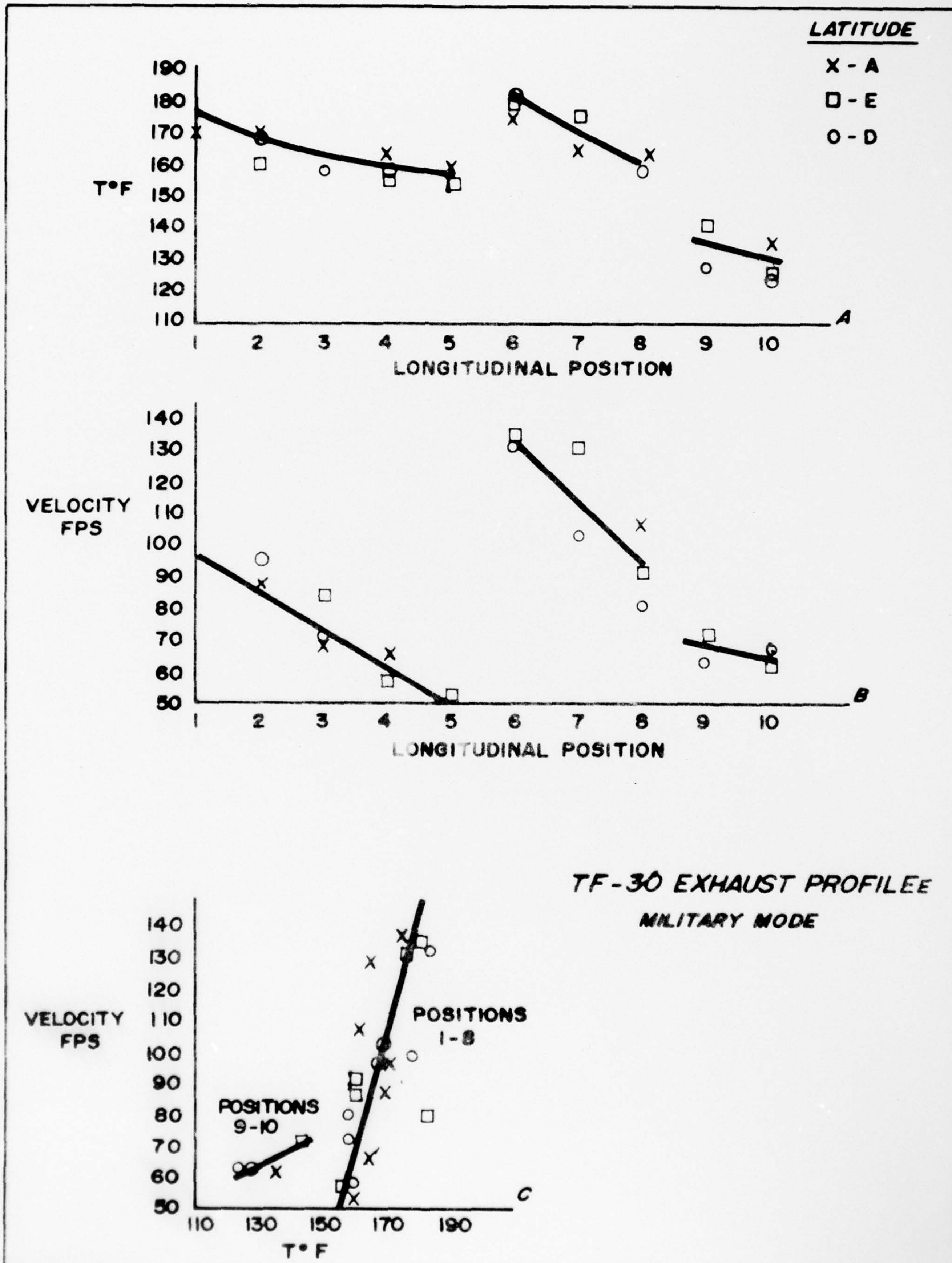
Of significant concern to both NARF and TESI personnel was the possible effect of the augmenter on engine performance. Initial data compared with correlation runs in the test cell under evaluation (JAX Black Point 1) indicated no observable variations in the relationships of:

TF-30, J-52	$Fn/\delta T_2$	(Thrust)	(Figs 10-3, 10-4)
TF-30, J-52	$N_2/\sqrt{\Theta T_2}$	(RPM)	(Figs 10-3, 10-4)
TF-30	$W_F/\delta T_2\sqrt{\Theta T_2}$	(Fuel Flow)	(Fig 10-3)
TF-30	$T_{T5}\,°F/\Theta T_2$	(Exhaust Gas Temp)	(Fig 10-3)

10.4.4 (Continued)

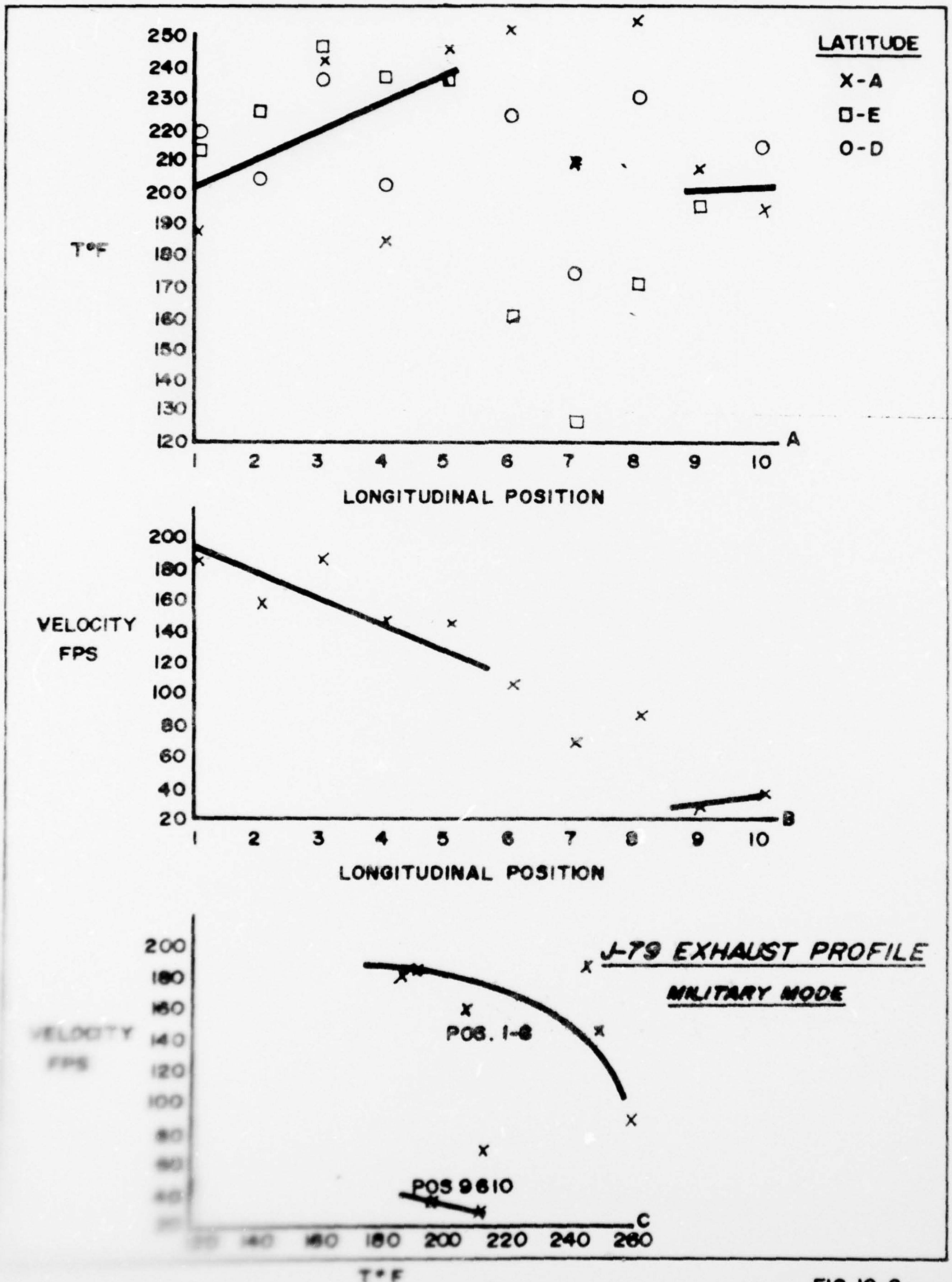
Some deviation was noted in J-52 performance with the TESI augmenter (Fig. 10-5). Data for J-79 characteristics were transmitted to General Electric Company. In a letter dated 18 January 1971 from General Electric (Exhibit Fig. 10-6), it was indicated "that the internal engine performance did not change (for test dates shown)."

The correlation curve transmitted by General Electric (Fig. 10-7) indicated no change in engine performance.



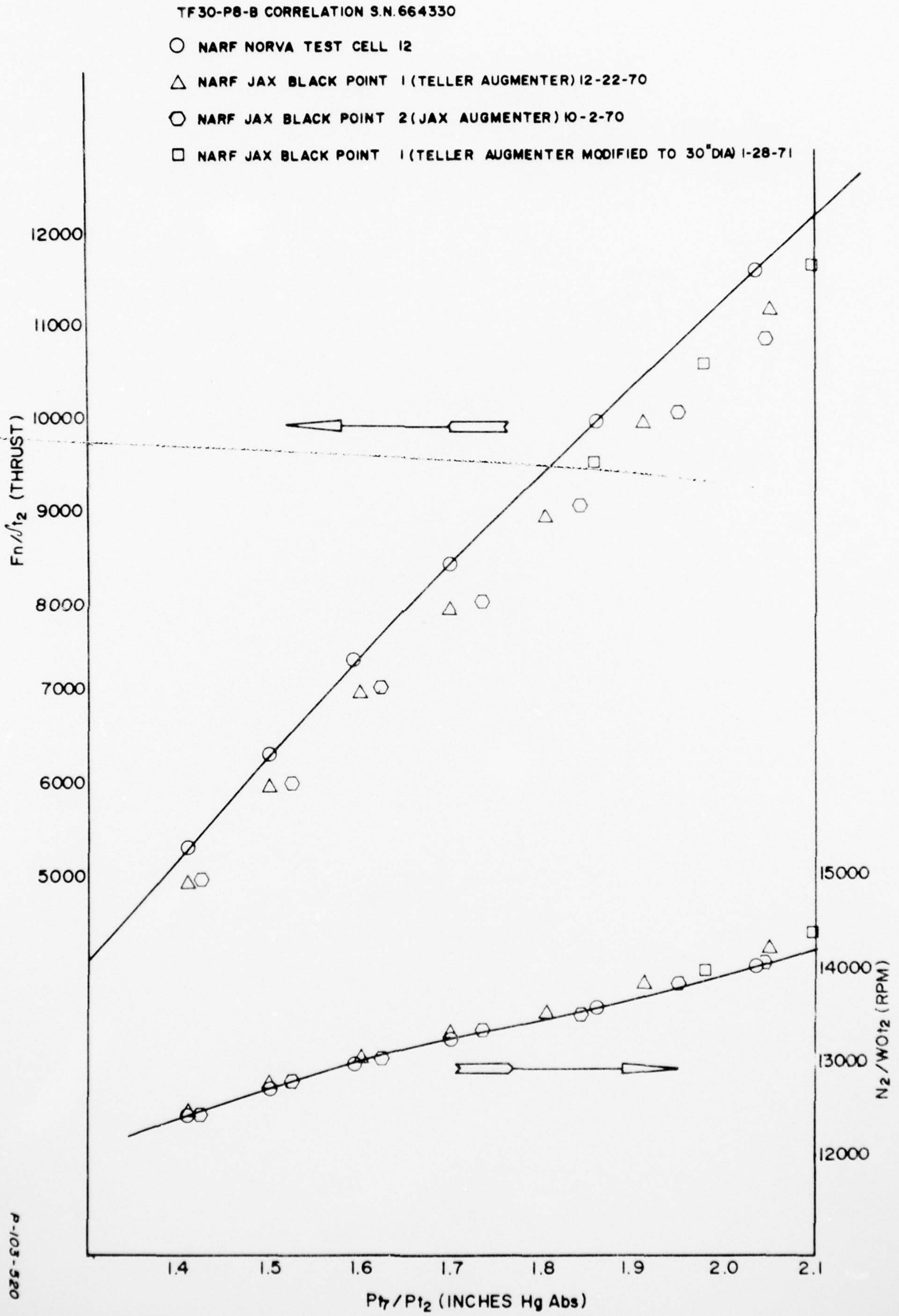
LATITUDE
X - A
□ - E
O - D
T°F
LONGITUDINAL POSITION
A
VELOCITY FPS
LONGITUDINAL POSITION
B
TF-30 EXHAUST PROFILEE
MILITARY MODE
VELOCITY FPS
POSITIONS 1-8
POSITIONS 9-10
T° F
C

FIG. 10-1



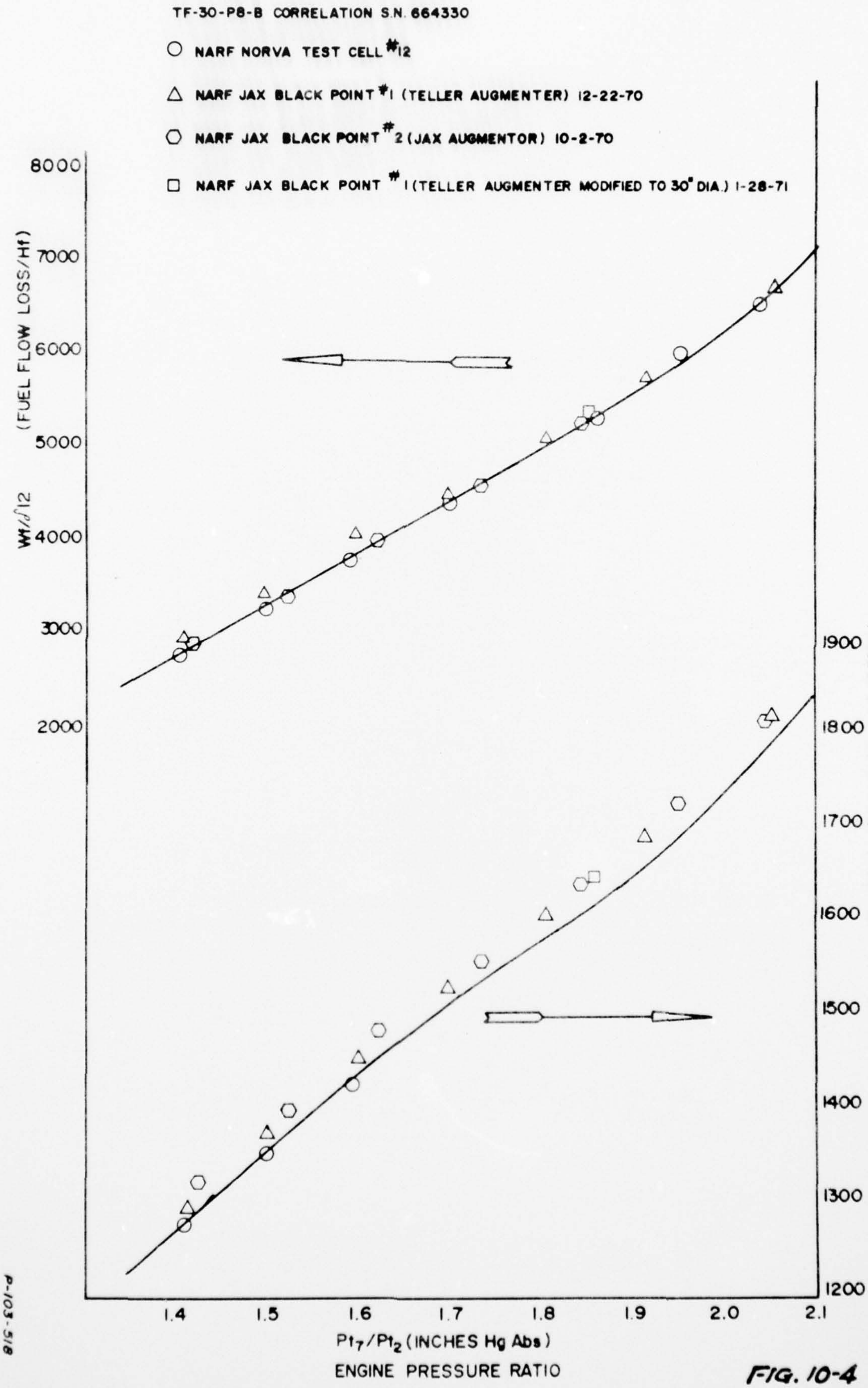
LATITUDE
X-A
□-E
O-D
T°F
250
240
230
220
210
200
190
180
170
160
150
140
130
120
A
1 2 3 4 5 6 7 8 9 10
LONGITUDINAL POSITION
VELOCITY FPS
200
180
160
140
120
100
80
60
40
20
B
1 2 3 4 5 6 7 8 9 10
LONGITUDINAL POSITION
J-79 EXHAUST PROFILE
MILITARY MODE
POS. 1-6
POS 9&10
200
180
160
140
120
100
80
60
180 200 220 240 260
C
T°F

FIG. 10-2



P-103-520

FIG 10-2



P-103-518

FIG. 10-4

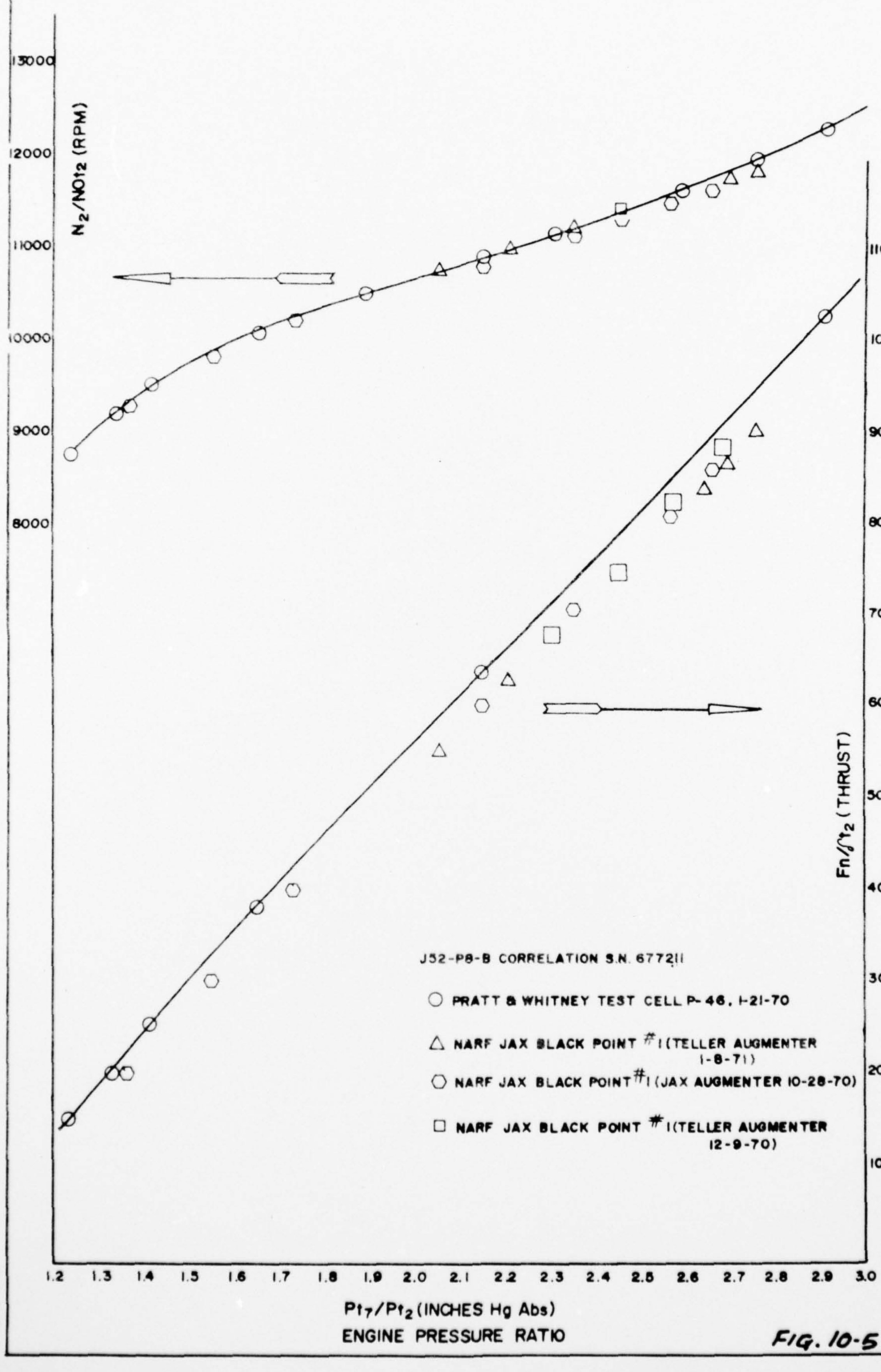


FIG. 10-5

P-103-517

GENERAL ELECTRIC

EVENDALE PLANT
CINCINNATI, OHIO 45215

MAIL DROP N134

DIAL COMM 8 • 332 3414

SUBJECT

NAS JACKSONVILLE PERFORMANCE COMPLAINT

COPIES:
RL Campbell
PL Love
TB Parker
HM Hicks
DRB 661
File

FILE: J79PA-1618

January 18, 1971

J.L. Price
J79 Project
N161

The curve (Engine Pumping Characteristics) for engine 421-731 requested by NAS Jacksonville is enclosed. This curve indicates that the internal engine performance did not change (for test dates shown).

It should be noted that this curve represents one engine only and since the same test cell was used, it is also probable one set of instrumentation is also involved. Should a considerable number of different engines be tested and also possibly in different test cells, the data will form a band with the width dependent on the actual engine quality and instrumentation variations.

S.R. Anderson

S.R. Anderson, Engineer
J79 Performance

/blc
Attachment
Curve: J79PA-1618-1

FIGURE 10-6

A-14-E

Enclosure (10)

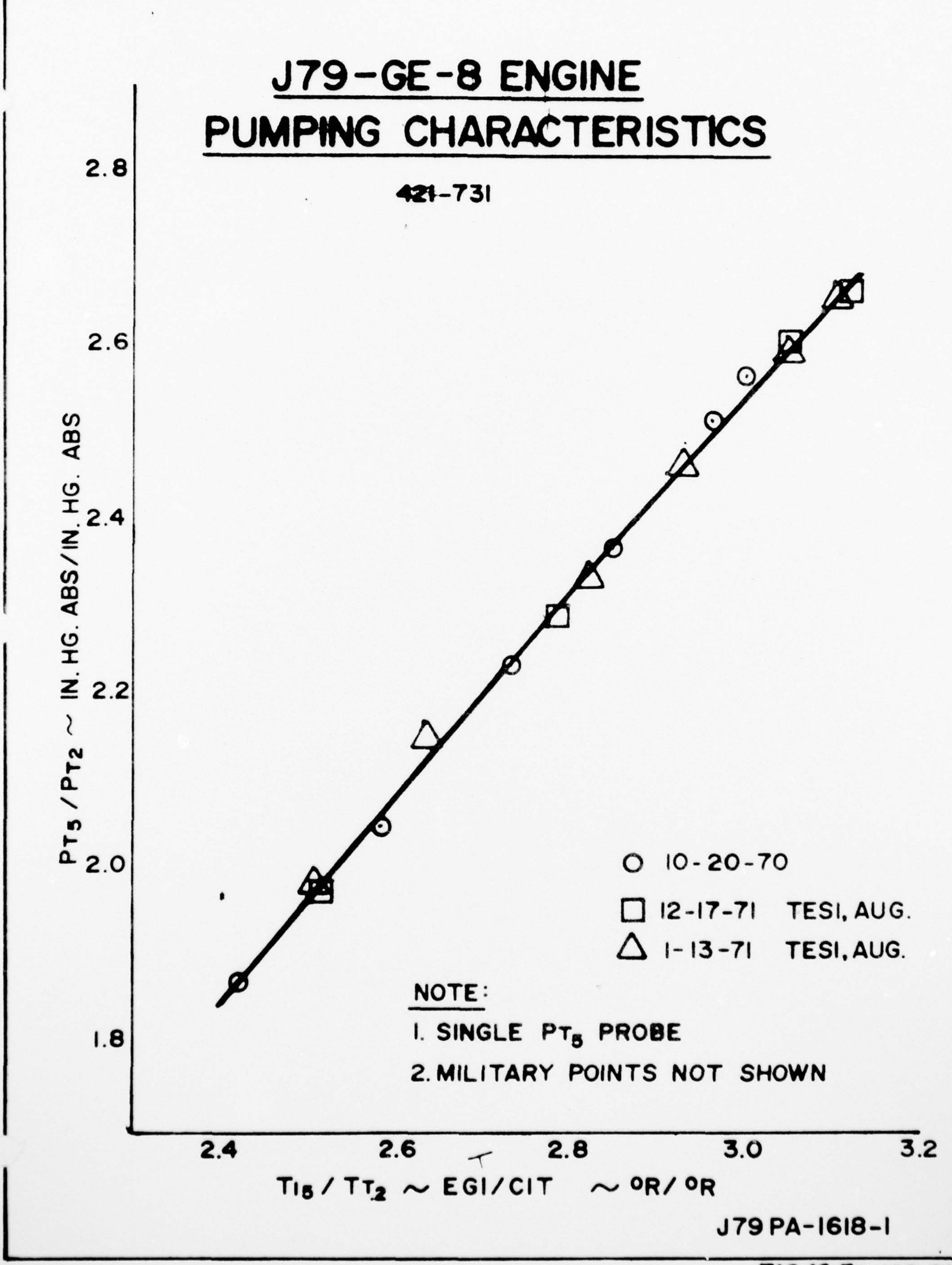


FIG 10-7 P-103-507

CONFORMANCE WITH ENVIRONMENTAL REQUIREMENTS

11.1 The criteria for recovery of particulate emissions from the exhaust of jet engine test stands were established in the "Pollution Abatement Study and Systems Analysis for Jet Engine Test Cells" (U.S. Navy Contract No. N62467-70-C-0078). These criteria were based on the following sources:

1 - Executive Order 11282 establishing conformance with state and local community regulations or, in the absence of such regulations, with Section 5 of the Executive Order;

2 - Section 5 (E.O. 11282) Paragraph 76.9 related to combustion processes establishing a permissible emission level of 0.28 per million Btu;

3 - "Air Quality Criteria for Particulate Matter" U.S. Department of Health, Education and Welfare (January 1969) that establishes the concern for effects on visibility of particles in the size range of 0.1-1 micron and the desirability of achieving ground level concentrations of these particles less than 0.000033 grains/ft^3.

The most restrictive local regulations, Bay Area Control District, California, establish a Ringleman Smoke Shade requirement of 1/2 except for 3 minute excursions to Ringleman 3. As a very approximate relationship, this limits the emission concentration to 0.010 grains/cu.ft. Baltimore, Maryland has recently established a zero Ringleman requirement.

On the basis of the Executive Order 11282, the emission level, converted to test stand gas flow, is limited to 0.008 grains/cu.ft. It was recommended in the initial study that a performance objective of 0.004 grains/cu.ft. be established so that even with transient difficulties, the 0.008 grains/cu.ft. level would be achieved.

11.2 Data obtained by Environment/One on the emissions from the scrubber system under the range of operating conditions required for engine testing, for three engines,

11.2 (Continued)

are as follows:

TABLE 11-1

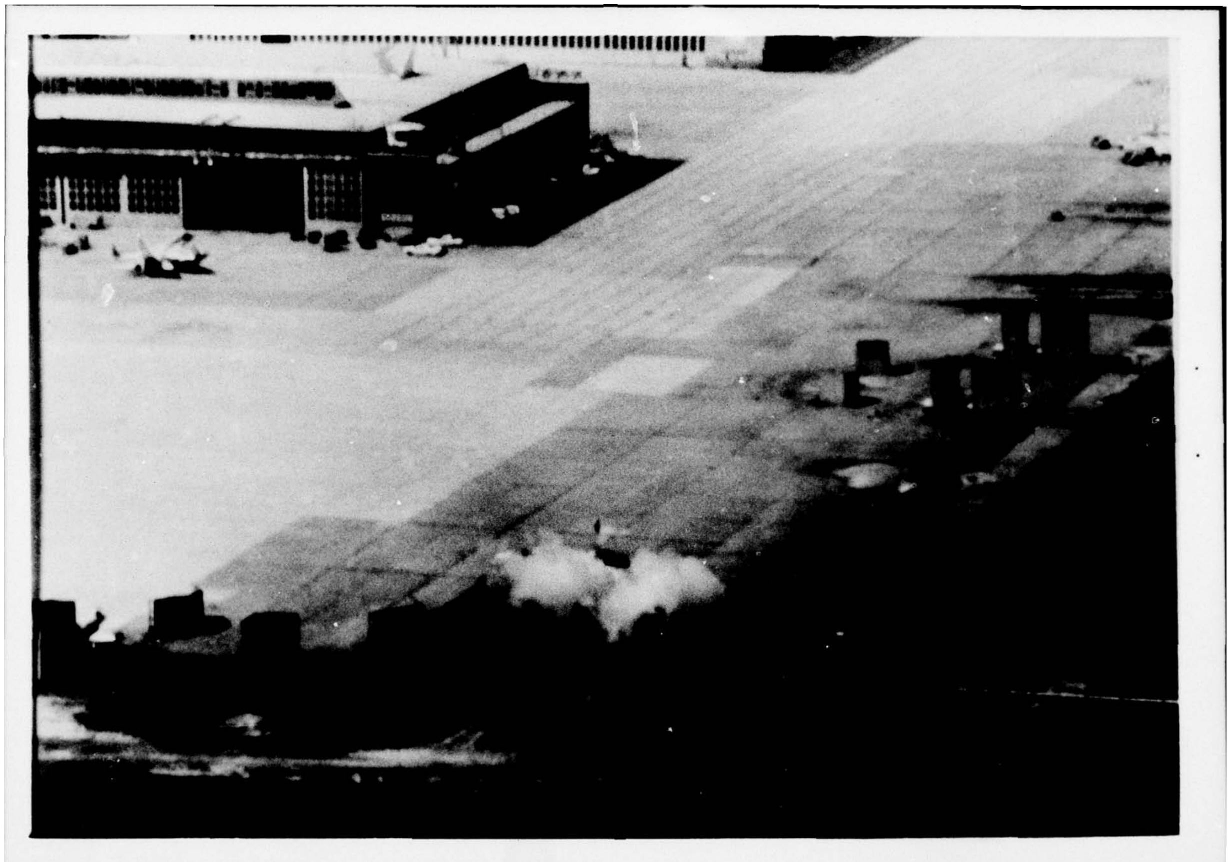
EMISSION LEVELS FROM TEST CONTROL SYSTEM

ENGINE	MODE	PARTICULATE EMISSIONS Grains/cu.ft.	RINGLEMAN	
J-79	Idle	0.0024	Less than 1/2	
	Normal	0.0029	" " "	
	Military	0.0024	" " "	
TF-30	Idle	0.0019	" " "	
	Normal	0.0014	" " "	
	Military	0.0018	" " "	
J-79	Idle	0.0052	" " "	These tests
	Normal	0.0029	" " "	are question-
	Military	0.0062	" " "	ed by ENVIRON-
	Max. A/B	0.0033	" " "	MENT/ONE.

In all conditions, the exhaust from the TESI scrubber system is well within the requirements of any established or recommended restrictions with emission levels ranging from 18% to 78% of the E.O. 11282 for performance and averaging 37% of the E.O. 11282 performance level. The analytical procedure conducted by Environment/One is indicated in Appendix 11-A.

A comparison of the visual or Ringleman conditions before and after introduction of the TEST system is indicated in Figures 11-1 through 11-4.

With respect to SO_2 and NO_x emissions, the normal concentrations within jet engine emissions prior to entering the scrubber were found to be less than 20 PPM for each gas or less than 15% of the limits in any projected legislation. Thus, control is not required.



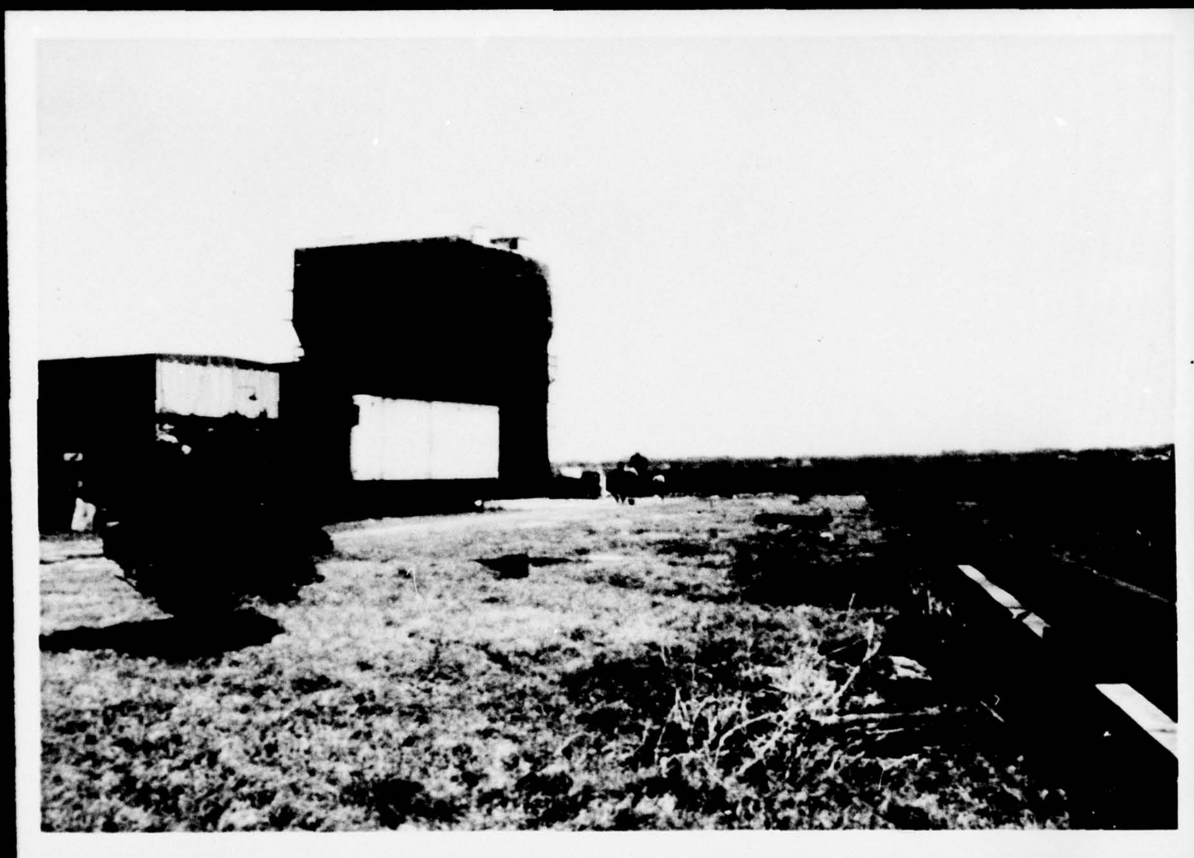


FIGURE 11.3

SECONDARY EFFECTS: Effluent Water

12.1 The effluent water temperature ranged from 74° at idle to 160°F at maximum afterburner mode for the J-79. This was higher than anticipated in design as indicated in the performance analysis section 7.

Based on the anticipated effluent water temperature and an outflow of 8,000 GPM, a water temperature profile was established for the river water. The basis for this analysis was not the point temperature development, but on the average heat release, resulting from the combustion of fuel over a test cycle, the typical cycle was considered to be 5 hours with 33% of the time consumed at military operation and 5% at afterburner. The average heat pickup was estimated at 15,000 Btu/sec resulting in an average temperature rise of the water of 13.8°F in the scrubber. The river flow velocity was assumed to be zero. The relationships established for river water rise for large warm effluent streams (Jen. Y. & Wiegel, R. L., Journal of the Power Division, Proc. AXCE, Paper No. 4801, April 1966) were as follows:

Equations

Based on semi-empirical model:

$$\frac{T_m - T_w}{T_D - T_w} = 7\frac{D}{X} \qquad (12.1)$$

Where:

T_m = Temperature along the center line of warm water jet, °F

T_w = Temperature of receiving water, 80°F

T_D = Temperature of the discharge water, °F

D = Diameter of the discharge pipe, ft.

X = Horizontal coordinate along the jet axis, measured from the point of discharge, ft.

7 = Empirical constant from the experimental data.

12.1 (Continued)

Equations

Based on semi-empirical model:

$$\frac{T - T_w}{T_m - T_w} = \exp - \left\{ 3F^{1/2} \left(\frac{y}{X} \right)^2 \right\} \quad (12.2)$$

Where:

T = Temperature at any point, °F

y = Horizontal coordinate normal to the jet axis measured from the jet axis, ft.

F = Froude no. defined as.

$$F = \frac{V_D}{\sqrt{\frac{\Delta\rho}{\rho_o} g D}} \quad (12.3)$$

Where:

V_D = Discharge velocity, ft/sec

ρ_o = Density of discharge water.

$\Delta\rho$ = $\rho_w - \rho_o$

ρ_w = Density of the receiving water.

g = 32.2 ft/sec^2

12.1 (Continued)

The computer printout of the average conditions are indicated in Figure 12-1. The printout indicates that a 4° rise in water temperature will occur in an area projecting 40 feet into the river and approximately 8 feet wide. In a test with a J-79 engine, the following information was obtained by NARF personnel (Figure 12-2):

TABLE 12-1

RIVER WATER TEMPERATURES

Mode of Operation	Distance from Bulkhead (feet)	Temperature °F within ±20' of Discharge Line 0	1'	2' (depth)
Military	40	85	66	66
Minimum A/B	40	100	69	68
Maximum A/B	80	80	72	70
Military	80	82	70	65

River Water Temperature = 61°F

The significantly larger increase in temperature compared with model projection is based on two factors. These data represent only 33% to 50% of the operation and the heat transfer capability of the scrubber is twice that originally projected.

The water quality data were obtained by NARF personnel and by Southern Analytical Laboratory (NAVFAC contract). The data relative to a significant factor, suspended solids, was determined only at NARF.

The data are reported in TABLES 12-2 and 12-3. The NARF suspended solids data are plotted in Figure 8-8.

TABLE 12-2

RESULTS OF ANALYSIS OF SCRUBBER WATER (NARF DATA)

	D.O. (APHA)			B.O.D. (APHA)			HYDROCLONES (ASTMD-1340)			UNDISSOLVED SOLIDS[1]			TURBIDITY (APHA)			
DATE	5/4	5/5	5/6	5/4	5/5	5/6	5/4	5/5	5/6	5/4	5/5	5/6	5/4	5/5	5/6	11/
ENGINE	J52	TF30	J79	J52	TF30	J79	J52	TF30	J79	J52	TF30	J79	J52	TF30	J79	J52
River	5.7	6.7	6.8	1.0	1.7	1.1	4	4	5	15	10.6	13.8	28	20	30	80
Idle	8.1	7.8	7.8	1.6	2.8	2.6	7	6	6	31.6	11.4	15.6	47	22	38	37
Normal Rated	6.4	6.4	7.0	1.4	1.2	2.3	6.0	7	7	87.0	14.6	21.4	31	24	62	37
Military	5.5	5.6	5.5	1.2	2.5	2.0	6.0	9	10	17.8	46.8	59	37	62	100	71
Max AB			2.3			1.8			12			32.6			70	

1 Filtered on 145 millipore

SOUTHERN ANALYTICAL LABORATORY

A DIVISION OF TECHNICAL SERVICES, INC.
103 STOCKTON STREET — P. O. BOX 628
JACKSONVILLE, FLORIDA 32201

Industrial Chemists

ANALYSIS OF INDUSTRIAL MATERIALS
RESEARCH - TECHNICAL REPORTS

June 15, 1971

Laboratory No. 8761

Sample of Waste Water

Date Received May 4, 5 & 6, 1971

For Commanding Officer, Southern Division, Naval Facilities Engineering Comma
P. O. Box 10068, Charleston, S. C. 29411 - Attn: Mr. R. B. Foster

Marks: Pollution Abatement Device, Jet Engine Test Cell, Naval Air Rework Facility - Black Point, NAS, Jacksonville, Florida

CERTIFICATE OF ANALYSIS OR TESTS

		Oxygen Demand, Biochemical	Dissolved Oxygen	Unburned Hydrocarbons	Turbidit
J-52 Engine	Military	3.2 mg/1	6.05 mg/1	0.7 mg/1	7 JU
	Idle	1.8 "	7.9 "	0.4 "	5 "
	Normal	2.3 "	6.6 "	0.6 "	40 "
TF-30 Engine	Idle	2.2 "	7.6 "	0.5 "	7 "
	Normal	2.4 "	6.3 "	0.7 "	4 "
	Military	2.0 "	6.0 "	0.8 "	15 "
J-79 Engine	Idle	2.4 "	7.1 "	0.9 "	5 "
	Military	2.5 "	5.6 "	0.9 "	40 "
	Max AB Run #1	4.4 "	4.4 "	1.87 "	66 "
	Max AB Run #2	2.7 "	4.9 "	1.2 "	48 "
River 5/4		1.4 "	6.8 "	0.4 "	4 "
River 5/5		1.6 "	6.8 "	0.3 "	4 "

TABLE 12-3

RESULTS OF ANALYSIS OF SCRUBBER WATER SOUTHERN ANALYTICAL LAB.

Respectfully submitted,

SOUTHERN ANALYTICAL LABORATORY, INC.

BY Harry C. Gray, Jr.

12.2 Comparison of BOD data indicates that the average increase reported by both groups is of the order of less than 1 PPM for all but A/B runs (Southern Analytical). Within the accuracy of analysis, there appears to be little or no reduction in dissolved oxygen with scatter of increases and decreases reported.

12.3 The NARF data indicate an increase in unburned hydrocarbons up to 7 PPM at A/B operation for the J-79 and a 2-3 PPM increase for military operations, whereas the Southern Analytical data indicate a maximum increase in 1.5 for A/B operation and a magnitude of 0.5 PPM for all other modes of operation.

12.4 The turbidity increase reported, observed by NARF personnel, was greatest for military ranging from 19 to 70 JU, whereas the Southern Analytical data indicated a rise of 11 to 36 JU for military mode and up to 62 for afterburner operation.

12.5 The undissolved solids increase was measured by NARF personnel and formed a basis for material balance for recovery of particulates by the TEST scrubber. The data for the TF-30 and J-79 were consistent through military and are indicated in Figure 8-8. The data for the J-52 runs were scattered. The only apparent inconsistency was the low quantity of particulates 18.8 PPM or 80 lb/hr of solids recovered during A/B operation of the J-79.

This discrepancy was due to the possibility that much of the unburned fuel (large particles) were captured by the internal section of the scrubber, were drained from the stack basin, and flowed through the separator into the river. Implied evidence of this phenomenon was obtained subsequent to the test program when various modes of separation of the particulates from circulation water were tested. Separation was achievable at times by centrifugation of the scrubber effluent water but not from the stack drainage. The only difference in effect can be attributed to the variation in specific gravity. The stack bottom particulates were probably covered with a film of JP-5 resulting in the lower specific gravity.

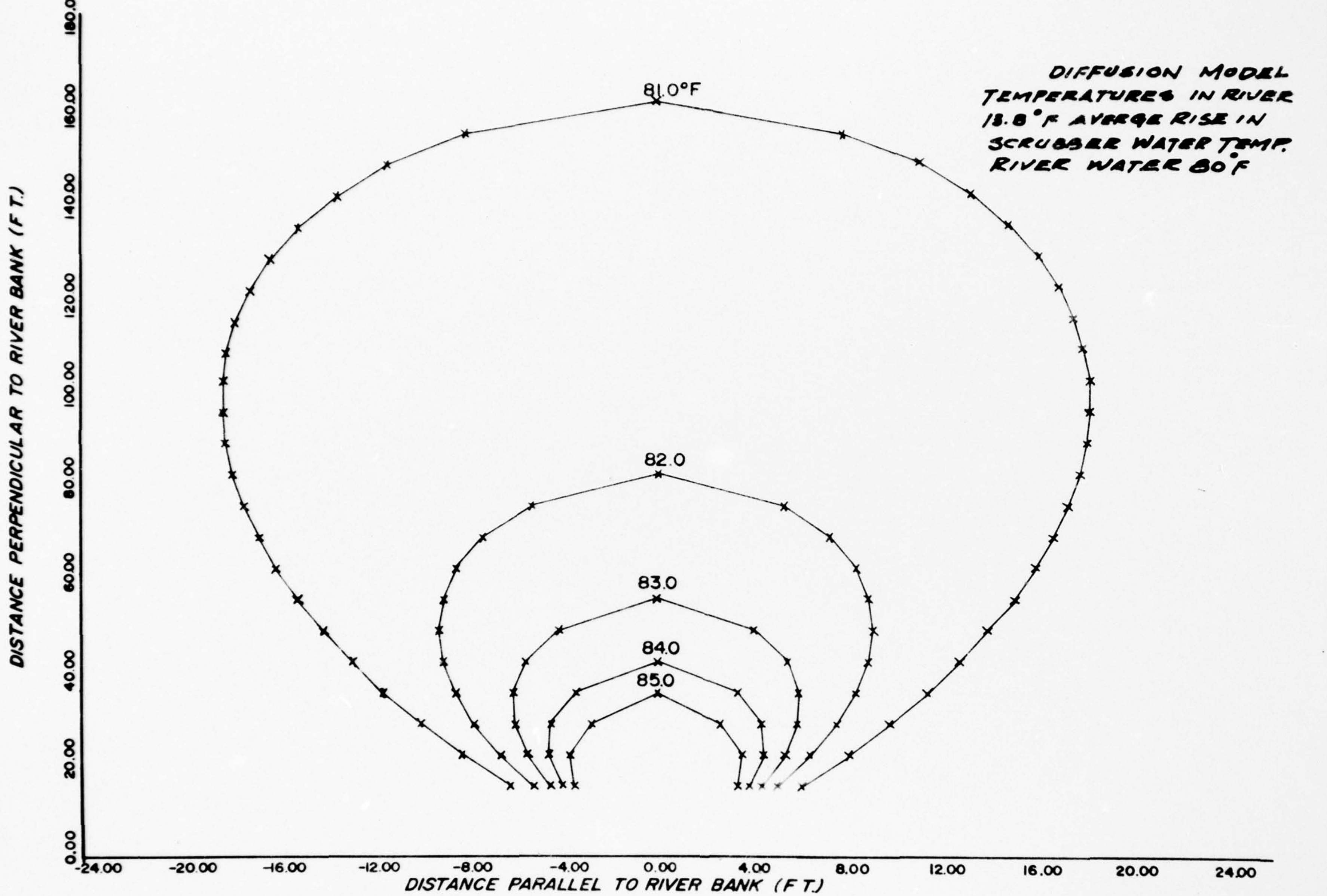


FIG 12-1

P-103-516

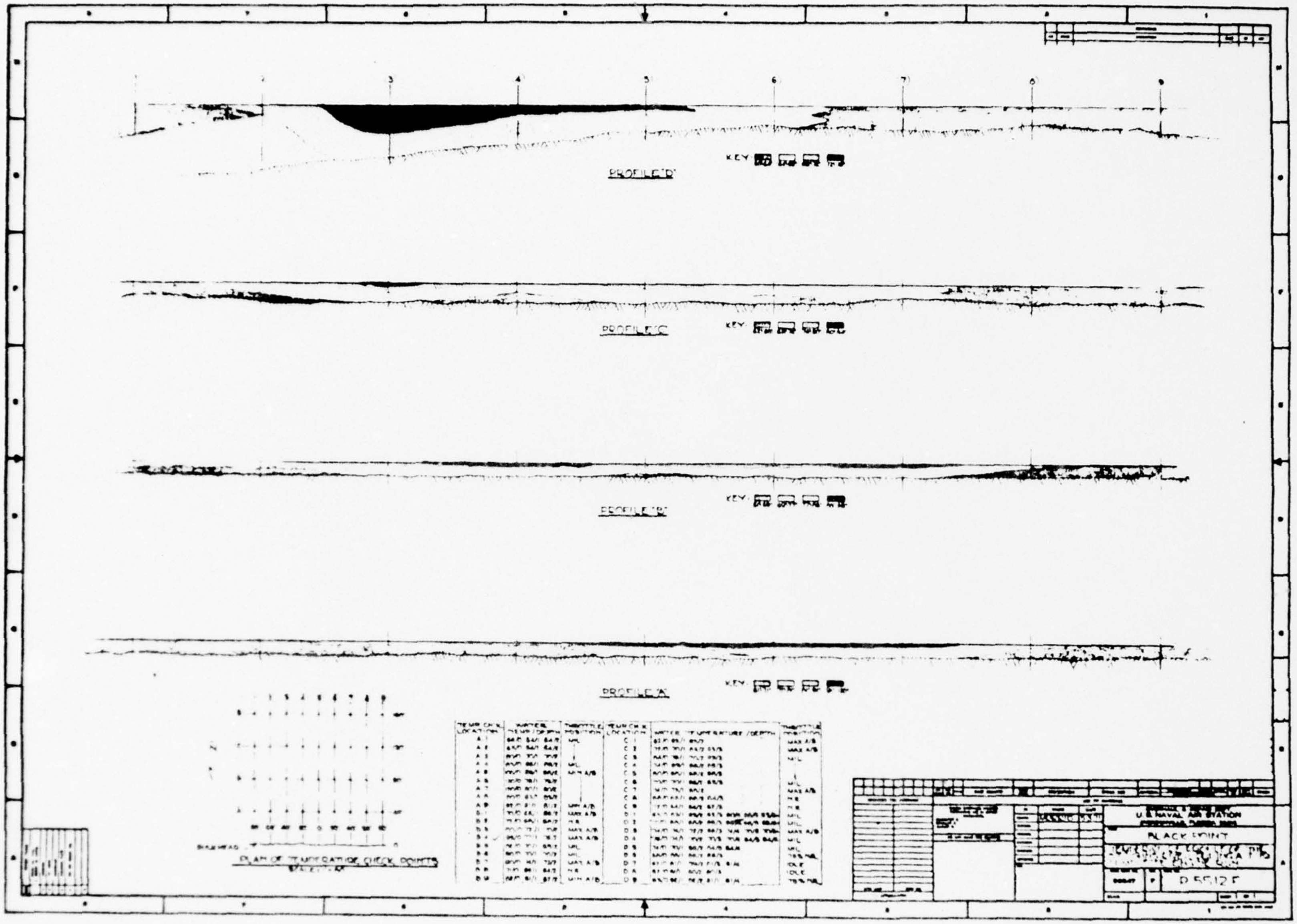

PROFILE 'D'
PROFILE 'C'
PROFILE 'B'
PROFILE 'A'
KEY
PLAN OF TEMPERATURE CHECK POINTS
U.S. NAVAL AIR STATION
BLACK POINT
D 5512 F

FIG. 12-2

SOUTHERN ANALYTICAL LABORATORY

A DIVISION OF TECHNICAL SERVICES, INC.
103 STOCKTON STREET — P. O. BOX 628
JACKSONVILLE, FLORIDA 32201

Industrial Chemists

ANALYSTS OF INDUSTRIAL MATERIALS
RESEARCH - TECHNICAL REPORTS

Laboratory No. 8386 April 21, 1971

Sample of Waste Waters

Date Received April 8, 1971

For Commanding Officer, Southern Division, Naval Facilities Engineering Command, P. O. Box 10068, Charleston, S. C. 29411

Marks: Attn: R. B. Foster

Black Point - NAS - Jacksonville, Fla.

CERTIFICATE OF ANALYSIS OR TESTS

	River Inlet	Max AB	Military	Idle
Oxygen Demand, Biochemical	4 mg/l	25 mg/l	6 mg/l	14 mg/l
Dissolved Oxygen	8.2 "	3.15 "	5.5 "	7.9 "
Turbidity (Jackson Units)	55 JU	95 JU	80 JU	65 JU
Hydrocarbons	5 mg/l	16 mg/l	10 mg/l	9 mg/l

579

TABLE 12-3

Respectfully submitted,

SOUTHERN ANALYTICAL LABORATORY, INC.

BY *Harvey C. Gray, Jr.*

SECONDARY EFFECTS: Sound Level

13.1 Significant reductions in sound level from the test stand (Black Point No. 1) were observed subsequent to installation of the TESI scrubber system. The comparison of the sound levels achieved with the total TESI system (scrubber and augmenter) compared with the prior conventional installation at Black Point Cell No. 1 are indicated in Figures 13-1, 13-2, and 13-3. The sound levels were obtained for operation with the:

TF-30	Military
J-79	Military
J-79	Maximum Afterburner

13.2 The three sets of curves form a similar pattern where significant reductions in sound level were achieved in the range of 31.5 - 400 cycles/sec and from 1000 to 16000 cycles/sec, and little or no change in the range of 400 - 2000 cycles/sec. The reduction in sound level as indicated by Overall "A" scale as measured by the Octave Band Analyzer ranged from 6 - 10 decibels for the engines evaluated.

TABLE 13-1

Overall "A" Scale Sound Levels

Decibels

Engine	Operating Mode	Without Scrubber	With Scrubber
TF-30	Military	100	90
J-79	Max A/B	103	95
J-79	Military	98	92

13.2 (Continued)

In the study report (Contract No. N62467-70-C-0078), it was projected that the packing would contribute to sound attenuation only at frequencies greater than 300 cycles/sec, but would have a significant effect only at frequencies greater than 1200 cycles/sec. (TABLE 9-4 Study Report). This magnitude of reduction was achieved with operation of the J-79 engine where reductions in sound level of 13 decibels was achieved at 4000 cycles/sec and a reduction of greater than 25 decibels was achieved at 8000 cycles/sec.

What was unanticipated was the reduction in sound level at the 16 - 250 cycle/sec range. The maximum reduction was 6 - 10 decibels at 63 cycles/sec.

Raw data in Appendix 13A.

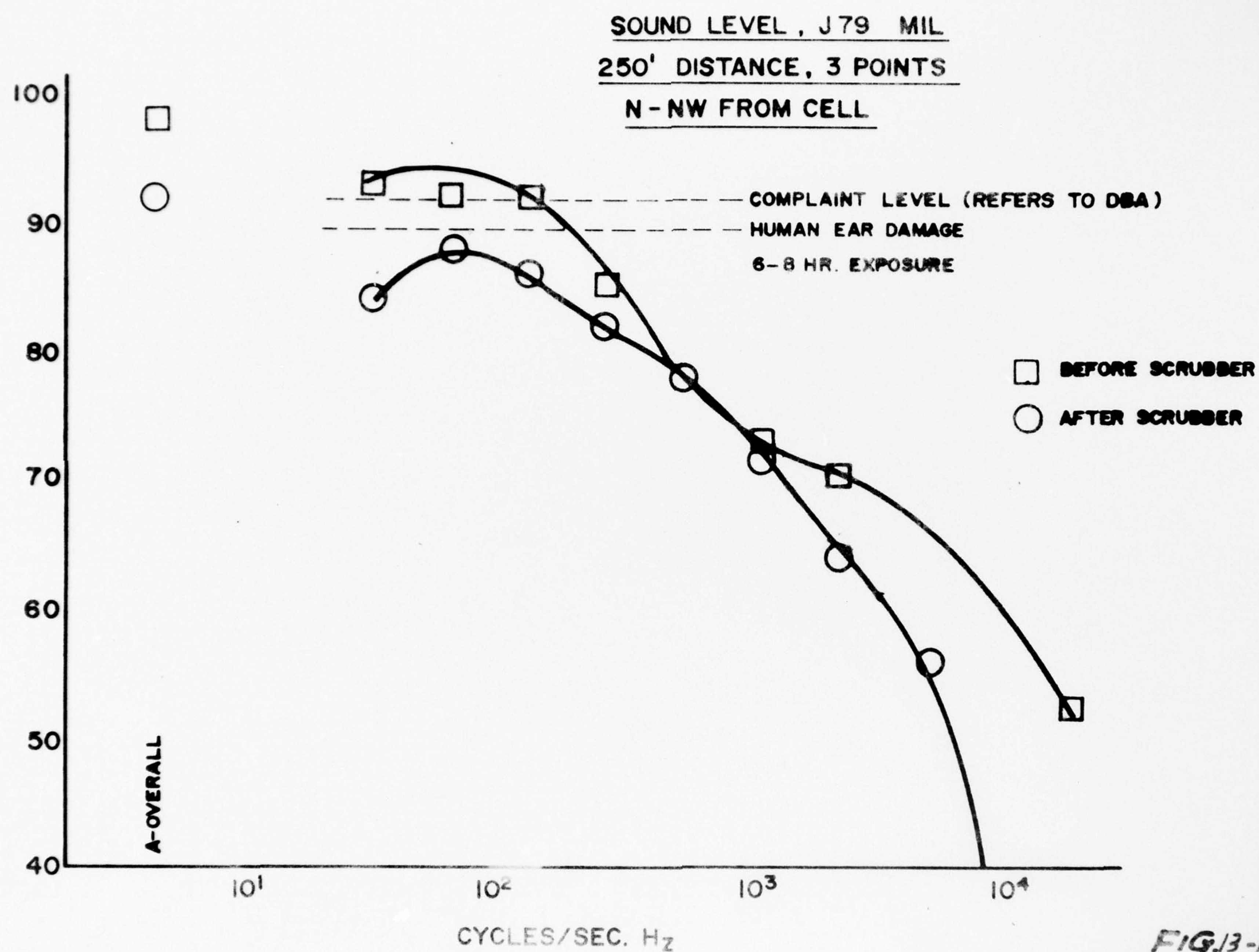

SOUND LEVEL, J79 MIL
250' DISTANCE, 3 POINTS
N-NW FROM CELL
COMPLAINT LEVEL (REFERS TO DBA)
HUMAN EAR DAMAGE
6-8 HR. EXPOSURE
BEFORE SCRUBBER
AFTER SCRUBBER
A-OVERALL
100
90
80
70
60
50
40
10^1
10^2
10^3
10^4
CYCLES/SEC. Hz

FIG. 13-1

P-103-502

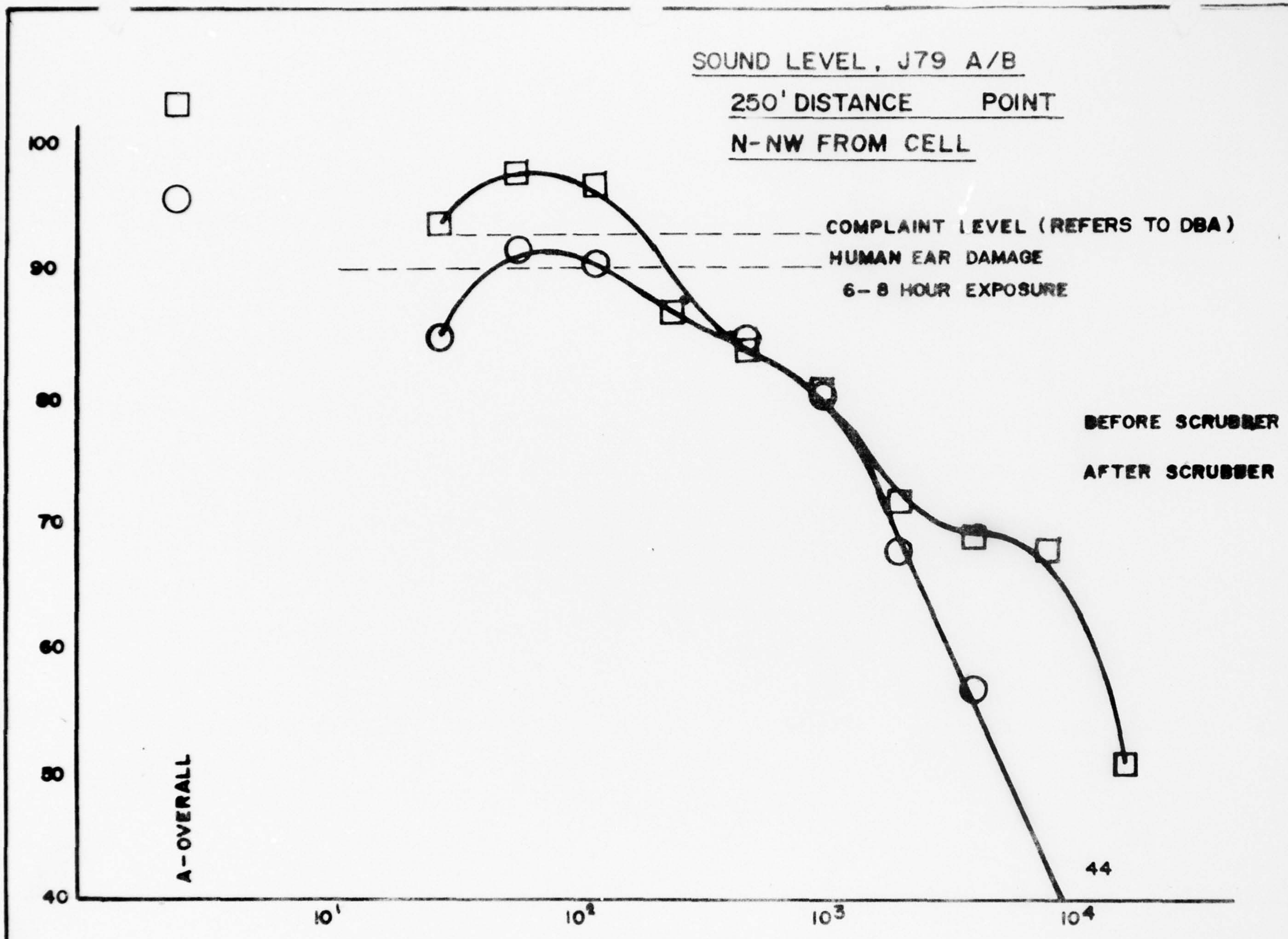


FIG 13-2

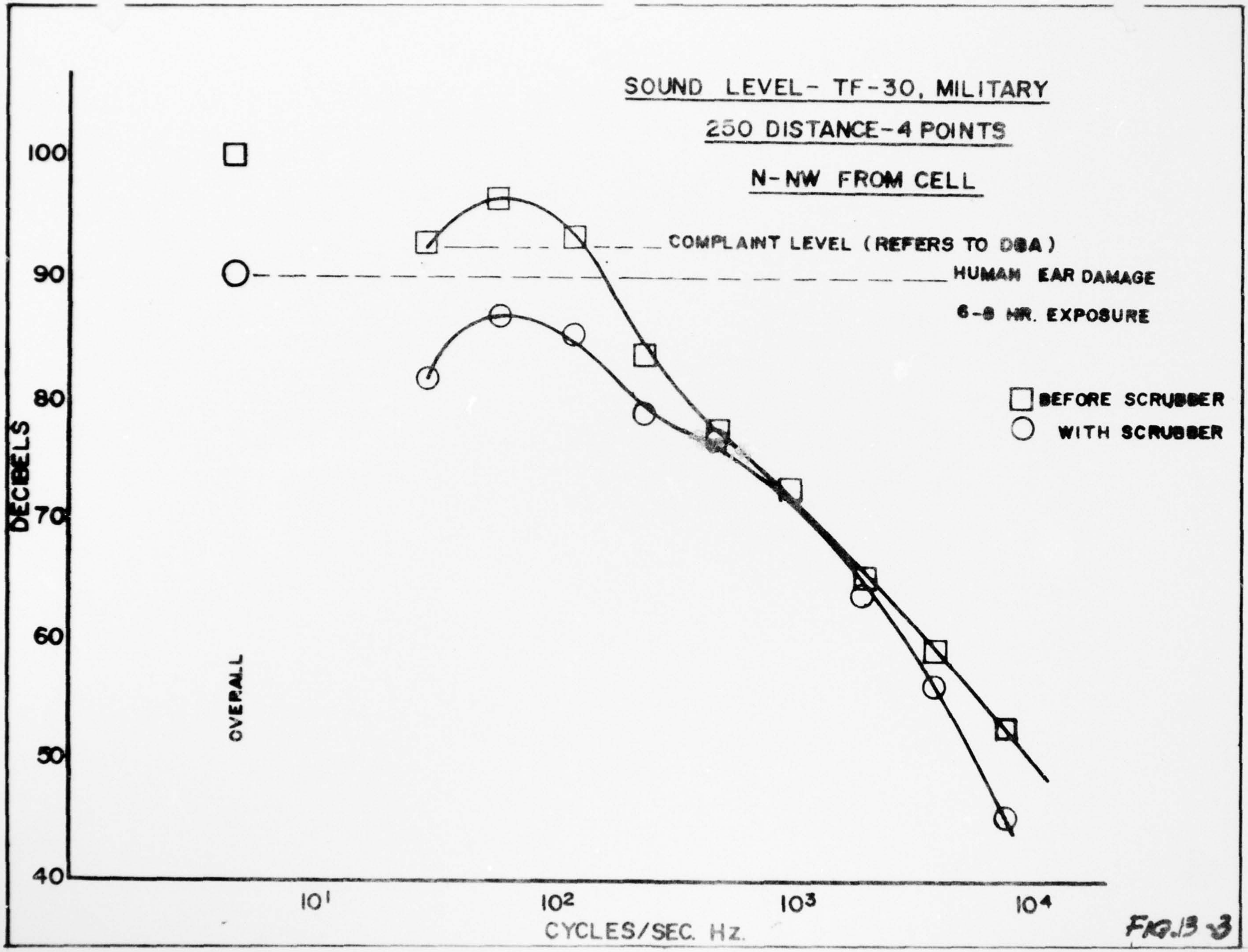

SOUND LEVEL- TF-30, MILITARY
250 DISTANCE-4 POINTS
N-NW FROM CELL
COMPLAINT LEVEL (REFERS TO DBA)
HUMAN EAR DAMAGE
6-8 HR. EXPOSURE
BEFORE SCRUBBER
WITH SCRUBBER
DECBELS
100
90
80
70
60
50
40
OVERALL
10^1
10^2
10^3
10^4
CYCLES/SEC. Hz.

FIG.13-3

Environment/One

The procedure for determination of effluent loading at the stack was as follows for six points.

1. Determine velocity for sample point by pitot tube and water manometer corrected for average effluent temperature. (8-1).

2. Select critical orifice allowing for isokinetic sampling at sample probe inlet. Probe inlet was fixed as 0.120 inches diameter. Five critical orifices were available, 11.5 to 26 liters/minute.

3. Locate two weight sampling probes at test point. Make pressure and temperature measurement at critical orifice for monitoring and flow corrections. Sample for 3 to 10 minutes, depending on effluent particle loading. Filter material used was Gilman Type "E" 47 mm.

4. Replace weight sampling probe with Milipore filter Type HA 47 mm and sampling probe for size distribution. Using same probe flow setting take 5-10-15 second samples after each probe pair change.

5. Repeat step (3-4) for two additional pairs of weight probe sample locations.

6. Wash out weight probes with water and collect on filter for weighing.

7. Take gas eamples at edge of effluent stream, with MSA Universal Sampling pump and detector tubes.

Engine parameters and exhaust gas temperature data were provided by test cell crew. Two engines were tested: J-79 for; idle, 95% load, afterburner min and afterburner max, and the J-52 engine for idle and military power settings.

ANALYSIS OF DATA

Weight of material on each filter was determined after bringing filter to same humidity condition at which initial clean weights have been determined. Weights were normalized for actual probe flow and sample times and averaged. Average wash water sample weight was added to filter weights and loading corrected for effluent discharge at 70°F, 14.7 psi. This loading is expressed in grains/ft^3.

ANALYSIS OF DATA (Continued)

A Milipore filter sample for each run was analyzed by microscope with 450 power and the size distribution determined by means of a Portion retical and stage micrometer. Counting locations were determined by random selection.

Gas analysis data were read directly from calibration charts. No indication was obtained on either the 103C or 103D SO_2 detection tubes. Data for the 95% and afterburner min. tests were not obtained. Gas concentration values were obtained only at the edge of the effluent stream and could be in error due to dilution factors.

Samples for water analyses were collected as follows:

1. The river water sample for background was taken from 3/4" pipe located on the side of the inlet water line approximately 2/3 of the distance from the river to the scrubber. One sample was taken at the beginning of each day's engine operations. NARF Jax April 6, 7 and 16, 1971 samples were 15 gals. and May 4, 5 and 6 were 5 gal. samples. Southern Analytical samples were all 5 gals. Water flow was 8000 gpm at time of samples.

2. Scrubber water effluent samples were taken at the outfall from the approximate center. The water was directed to the sample bottles through a 2" pipe which was 6' long. One sample was collected during each engine setting. The volume of sample taken and effluent water flow were the same as reported in para. 1 above.

The train used consists of the following: The line from the manifold feeds into an impinger consisting of a bubbling impinger containing distilled water followed by a similar impinger with no water. The output of the second impinger is transferred directly into a Swinex - 47 filter holder containing a Gelman Type A glass 47mm filter. This train is followed by the air moving system consisting of a flow adjusting needle valve, a thermometer, a Thomas Series 727-CA-39 vacuum pump and a Dwyer Rotameter. Although the flow was monitored constantly during all runs, it was not necessary to make any adjustments.

The gases were sampled as follows: Horizontal slotted pipes were mounted at two points in the outlet guides at the 8 ft and 12 ft level. Projecting out of the slots in these pipes were intake nozzles consisting of stainless steel tubing, .250 inch O.D., .010 inch wall 4 inches long. Six of these nozzles were manifolded together by connection to copper pipe for each level of sampling, so that they were uniformly spaced ($\pm$1 inch) five feet apart along the length of the slotted pipe. This manifold was connected to the sampling train by an 8 foot length of Tygon tubing.

The procedure during a run was as follows: Upon a signal from the engine operator that the desired engine condition had been reached, the pumps were all started. Time was measured from this point, by starting a stopwatch. The flow was immediately adjusted and the operation of each train checked. At the end of the selected time, the pumps were stopped and the operator signaled to stop the engine. After the engine was shut down, the nozzles were removed, all the pipes were flushed with acetone, the Tygon tubing flushed with water and the impingers were washed with acetone. All of these flushings were preserved with the bubbler water as part of the sample collected for that run. The filters were removed and each placed in a separate plastic Petri dish. The devices were then reassembled for the following run:

It had been our intention to point the nozzles into the direction of flow by observing the static pressure while rotating the slotted pipe, and stopping at the point where a maximum was observed. However, the flow rate was so slow that no variation could be observed. Therefore, we simply pointed the nozzles by visually aligning them with the flow.

The temperature at the impinger rose rather slowly during each run at a maximum of about 120°F.

The loadings as reported were the averages of the weighings of material gathered on two runs each, from a total of 12 points.

1. The sampling train employed is as follows:

a. 10' stainless steel probe connected to the 1st impinger by means of a 10" long teflon lined silicone rubber tube.

b. Dry Greenberg-Smith Impinger (cooled with 1,1,1-trichloroethane and dry ice.)

c. 2 Greenberg-Smith Impingers containing 250 cc water.

d. 1 Filter assembly containing a Millipore Type AP25 glass prefilter, one .45 micron Milipore filter, one .22 micron Milipore filter.

e. 1 Impinger with desicant.

f. Meriane PFB laminar flowmeter with connections, a thermocouple, differential pressure gauge, and absolute pressure gauge.

g. Needle Valve.

h. Vacuum pump

2. Nine points were sampled at 10 minutes for each point for a total volume sampled of 30-40 c.f. Stack velocity was determined by means of a pitot tube and uncleaned wavometer and temperature by means of a thermocouple and Honeywell detector.

Correct settings for sampling rate were determined from raw data by means of a computer program designed to give stops at air velocity at standard day conditions, air volume in cfm, flow rate in laminal air flow meter, differential pressure required for flow meter rate. Calculations required 10-20 seconds and were rechecked after initial setting. Accuracy of equipment use is $\pm$ 1.0%

3. Samplings collected were washed from the impingers and probed with distilled water and acetone. All samples were evaporated to dryness and the filters were dried to constant weight, to determine total solids weight. Total weights were from 11 to 68 mg.

TEST DATA - SCRUBBER

APPENDIX 9A

BLACK POINT TEST CELL
SCRUBBER TEST PROGRAM

T-2 = 56°

3/20/71

	Engine Characteristics			Water Flow GPM		TEMPERATURE °F: EXIT at stack before entering scrubber								Exit fm 2 locations on Scrubber				P
Time	No.	RPM	Thrust	Quench	Tower	17	18	19	20	21	22	23	24	0-1	0-2	River Water IN	Scrubber Water OUT	In. H_2O Internal
0907	J-79	5012	340	50	4500	84	74	88	90	89	92	68	65	68	62	60	63	
0915	"		340/1000	50	4500	98	89	128	100	100	102	83	82	66	62	"	64	0.1
0925	"	5720	1020	50	4500	102	98		108	105	105	102	95	68	62	"	68	0.14
0935	"	5930	1540	150		104	101		105	104	105	104	100	62	62	"	68	
0940	"	6095	2020	150	4500	104	101		105	105	105	104	101	65	62	"	72	0.24
0945	"	6307	3000	150	4500	106	105		107	106	106	106	106	66	61	"	76	0.35
0950	"	6447	4000	150	4500	110	110		112	112	112	112	112	66	64	"	80	0.31
0955	"	6562	5000	150	4500	116	114		116	116	116	115	115	68	64	"	85	
1000	"					116	116		116	116	118	116	117	67	64	"	85	0.4
1000	"	6615	5500	150	4500	118	118		120	119	120	119	119	68	63	"	88	0.4
1010	"	6680	6000	150	4500	121	121		123	122	123	122	121	68	64	"	90	1.8[1]
1020	"	6753	6500	150	4500	122	122		124	124	125	124	-	66	64	"	95	2.8[1]
1030	"	6825	7050	150	4500	123	123		126	125	126	125		66	66	"	98	4.0[1]

1 - Water in Manometer lines results in question.

TEST DATA - SCRUBBER

APPENDIX 9A

BLACK POINT TEST CELL
SCRUBBER TEST PROGRAM

3/20/71

Ambient - 58°F

	Engine Characteristics			Water Flow GPM		TEMPERATURE °F — EXIT at stack before entering scrubber							Exit fm 2 locations on Scrubber		River Water	Scrubber Water	P
Time	No.	RPM	Thrust	Quench	Tower	17	18	19	20	21	22	23	0-1	0-2	IN	OUT	In. H_2O Internal
1125	J-79			300	6100												
1135	"	6966	8000			128	126		130	130	130	127	67	63	65	92	5[1]
1150	"	7100	9300	300	6900	131	130		133	134	124	131	65	65	"	100	8[1]
1200	"	7278	10240	300	6900	132	132		135	136	136	133	72	66	"	102	10[1]
1207	"	7691	10780	300	6900	135	134		137	139	140	136	82	84	"	107	10[1]
1350	"	7687	10880	Full Front	7400	133	128		130	133	132	130	78	68	"	103	8[1]
1357 To Min AB	"	7688	10820	"	7400	133	132		136	137	138	134	77	66	"	104	8[1]
1405	"	7698	13080	Both Ring & Venturi	7400	149	140		146	148	149	145	112	72	"	131	
1410	"	6699	13140	" "		153	154		156	156	158	154	119	84	"	136	11.6[1]
1420 To Max AB	"	7696	14240	" "	7400	160	146		151	154	156	152	118	90	"	144	6.1[1]
1530	"		16600														
1545	"	7700	16600	" "	8100	162	144		152	156	150	160	160	150	"	168	
1547	"					175	168		170	172	174	174	172	160	"		8.6[1]

1 - Water in Manometer lines results in question.

TEST DATA - SCRUBBER

APPENDIX 9A

BLACK POINT TEST CELL
SCRUBBER TEST PROGRAM

4/16/71

	Engine Characteristics			Water Flow GPM		TEMPERATURE °F: EXIT at stack before entering scrubber							Exit fm 2 locations on Scrubber		River Water	Scrubber Water		P
Time	No.	RPM	Thrust	Quench	Tower	17	18	19	20	21	22	23	0-1	0-2	IN	OUT	OUT-FALL	In. H_2O Internal
1010	TF-30	740	560	100	8000	92	85	-	97	98	98	86	78	83	73	75		
1015	"	7110	6320	100	-	111	107	-	114	114	114	107	78	78	74	90		
1030	"	4780	8320	700	-	114	113	-	120	119	118	114	76	78	74	95		
1045	"	6940	11200	700	-	124	122	-	128	127	126	123	76	75	74	105	102	
1100	"	4720	8240	700	-	114	113	-	120	119	117	115	76	76	74	94	91	
1110	"	3640	6390	100	-	112	111	-	116	116	114	112	75	75	74	90	86	
1120	"	740	700	100	-	96	88	-	105	100	99	92	74	74	74	76	74	

J-79 Engine on 8 April 1971

1330	J-79-10	5043	200	100	8300	114	100	86	112	111	113	115						
1337	"	7029	7500	600	8300	116	106	95	120	117	118	117	62	90	66	ND		
1343	"	7485	11300	600	8300	135	133	130	140	138	139	135	67	72	64	"		
1350	"	7484	13540	1100	8300	157	160	157	162	167	158	155	64	93	64	"		
1355	"	7483	17180	1100	8300	175	170	163	175	174	177	170	142	174	64	"		
1400	"	7231	9200	600	8300	130	135	118	150	147	146	147	64	68	-	"		
1410	"	6985	7300	600	8300	125	126	107	138	129	127	127						
1420	"	5050	200	100	8300	118	107	82	132	122	121	122						
1430	"	7490	11400	600	8300	135	136	122	147	142	140	138	68	72	64	ND		
1510	"	7495	11360	600	8300	131	124	-	139	137	134	131	68	72	64	"		
1515	"	7495	11360	600	6000	134	134	-	145	141	139	137	74	85	64	"		
1517	"	7495	11360	600	5000								82	104	64	"		
1520	"	7495	11360	600	4000								85	120	64	"		
1523	"				3000								102	138	64	"		

TEST DATA - SCRUBBER

APPENDIX 9A

5/4/71

BLACK POINT TEST CELL
SCRUBBER TEST PROGRAM

	Engine Characteristics			Water Flow GPM		TEMPERATURE °F: EXIT at stack before entering scrubber							Exit fm 2 locations on Scrubber		River Water	Scrubber Water		P In. H_2O
Time	No.	RPM	Thrust	Quench	Tower	17	18	19	20	21	22	23	0-1	0-2	IN	OUT	OUT-FALL	Internal
1120	J-52	770	480	100		90	84	82	98	98	98	87	80	88	76	85		
1325	"	6100	7540	600		124	120	118	124	122	126	120	82	80	78	99	90	
1540	"	7440	8840	600		130	130	117	132	132	134	229	87	85	82	110	101	
			5/5/71										5/5/71					
0845	TF-30	770	740	100		88	83	82	90	90	92	83	86	80	78	80		
1020	"	4970	8640	600		114	115	112	117	117	116	114	80	80	78	96	91	
1310	"	7150	11560	600		123	122	116	123	123	124	120	80	79	78	104	102	
			5/6/71										5/6/71					
0820	J-79	1140	430	100		115	104	104	114	113	114	110	82	80	78	80	78	
1055	"	8640	10100	600		136	135	130	138	136	138	135	88	83	77	114	108	
1230	"	9170	10660	600		138	138	134	140	139	140	137	88	84	92	118	112	
1400	"	33000	15960	1000		180	168	184	168	166	179	172	162	146	80	172	168	

SOUND PRE...URE LEVEL (SPL) STUDY DATA SHEET
6ND NAS JAX 6260/2 (3-68)

LOCATION	DATE	TIME
BP-1	12-30-70	1030

NOISE SOURCE: TF-30 664330 AT MIL POWER Fn 11550 Wf 7550 H2O ≡ 1606PH

DATA BY:

SOUND LEVEL METER: SER. NO. — OCTAVE BAND ANALYZER: 1558-BP — SER. NO. — MICROPHONE: 1560-PC

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	31.5	63	125	250	500	1000	2000	4000	8000	16,000
			FREQUENCY ANALYSIS BY OCTAVE BAND CENTER FREQUENCIES (Hz)									
1	84	104	96	101	98	89	82	75	70	65	60	<44
2	80	100	94	97	95	85	78	75	66	62	56	<44
3	76	97	91	94	89	79	71	70	59	51	46	<44
4	77	99	92	92	90	80	76	67	60	55	48	<44
5	73	96	90	93	82	74	73	66	58	57	52	<44
6	86	99	94	98	92	86	85	79	75	70	65	47
7	82	105	97	102	98	93	88	84	82	80	70	52
8	88	104	98	101	99	95	87	85	77	74	68	50
9	89	103	97	100	98	90	84	80	77	77	67	52
10	90	103	98	101	92	85	82	73	68	66	58	<44

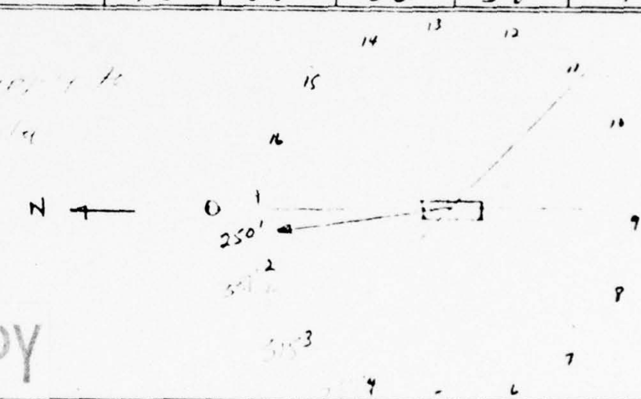
REMARKS:

TEMP 48°F

WIND VEL 10K

" DIR 010°

REL HUM 80%



...SSURE LEVEL (SPL) STUDY DATA SHEET

JAX 6260/2 (3-68)

LOCATION	DATE	TIME
NOISE SOURCE		DATA BY

SOUND LEVEL METER	SER. NO	OCTAVE BAND ANALYZER	SER. NO	MICROPHONE

POSITION	db A "A" SCALE	OVERALL	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz)									
		20 Hz - 20 KHz	31.5	63	125	250	500	1000	2000	4000	8000	16,000
11	89	104	98	100	96	91	89	83	78	75	69	52
12	88	105	96	103	94	91	88	83	75	74	68	52
13	89	105	97	103	94	92	87	84	76	72	66	49
14	91	105	99	101	97	90	91	85	77	76	67	49
15	89	105	100	101	99	88	86	83	80	78	67	49
16	88	105	98	100	99	89	83	81	76	71	66	48

REMARKS

SOUND P JRE LEVEL (SPL) STUDY DATA SHEET
CND NAS JAX 6260/2 (3-68)

LOCATION	DATE	TIME
NAVAIREWORKFAC JAX FLA BIACK POINT TEST CELLS (EAST CELL # 1)	8 JULY 1970	0845 - 1315

NOISE SOURCE	DATA BY
J-79-8 ENGINE (Bu. No. 401649) in East Test Cell	BYRD-MORRISON-ALLE

SOUND LEVEL METER	SER NO	OCTAVE BAND ANALYZER	SER NO	MICROPHONE
GENERAL RADIO CO.	OCTAVE	BAND NOISE ANALYZER	888	CERAMIC

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	16,000
1 Mil. Pwr.	84	101	95	97	95	87	79	75	73	69	65	51
1 Afterburner	88	103	96	98	96	88	85	80	81	80	78	62
2 Mil. Pwr.	83	98	92	92	92	87	78	74	73	69	67	505
2 Afterburner	90	101	94	94	93	91	85	81	84	80	79	63
3 Mil Pwr	77	95	91	88	87	80	71	69	64	60	55	44
3 Afterburner	80	97	92	90	87	82	73	74	72	68	67	52
4 Mil Pwr	76	94	89	87	85	75	71	72	67	62	60	45
4 Afterburner	82	95	89	88	85	81	77	73	74	72	70	57
5 Mil Pwr	73	93	86	89	81	71	70	68	64	58	56	44
5 Afterburner	78	95	88	89	82	73	73	71	71	70	69	54

REMARKS:

SOUND PRESSURE LEVEL (SPL) STUDY DATA SHEET
6ND NAS JAX 6260/2 (3-68)

LOCATION	DATE	TIME
NAVAIREWORKFAC JAX FLA BLACK POINT TEST CELLS (EAST CELL # 1)	8 JULY 1970	0745 - 1315

NOISE SOURCE	DATA BY
J-79-8 ENGINE (Bu. No. 401649) in East Test Cell	BYRD-MCRRISON-ALLEN

SOUND LEVEL METER	SER NO	OCTAVE BAND ANALYZER	SER NO	MICROPHONE
GENERAL RADIO CO.	OCTAVE	BAND NOISE ANALYZER	808	CERAMIC

POSITION		db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz)									
				31.5	63	125	250	500	1000	2000	4000	8000	16,000
6	Mil Pwr	84	98	93	95	91	83	81	81	76	70	68	53
6	Afterburner	92	101	95	95	91	86	88	86	83	82	83	69
7	Mil Pwr	85	99	92	95	94	83	83	80	73	66	60	45
7	Afterburner	88	101	96	96	94	84	83	82	79	75	74	59
8	Mil Pwr	88	101	95	96	94	92	86	82	78	74	69	54
8	Afterburner	94	104	98	98	94	94	90	85	86	86	85	71
9	Mil Pwr	88	101	95	96	93	92	86	82	76	72	66	51
9	Afterburner	94	104	100	98	94	94	90	86	87	84	83	69
10	Mil Pwr	94	103	95	97	96	93	89	87	86	85	79	65
10	Afterburner	98	106	100	98	96	95	93	92	92	91	88	73

REMARKS:

J-79-8 . 250'

SOUND PRESSURE LEVEL (SPL) STUDY DATA SHEET
6ND NAS JA ...50/2 (3-68)

Continuation Data Sheet (2 of 3)

LOCATION	DATE	TIME
NAVAIREWORKFAC JAX FLA BLACK POINT TEST CELLS (EAST CELL #1)	8 JULY 1970	0845 - 1315
NOISE SOURCE: J-79-8 ENGINE (Bu. No. 401649) in East Test Cell		DATA BY: BYRD-MORRISON-ALL

SOUND LEVEL METER	SER NO	OCTAVE BAND ANALYZER	SER NO	MICROPHONE

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	16,000
11 Mil. Pwr.	92	102	94	98	93	91	89	87	86	81	75	63
11 Afterburner	97	105	97	98	95	93	93	91	90	90	88	73
12 Mil. Pwr.	93	102	94	97	93	92	90	87	83	80	75	65
12 Afterburner	97	104	96	98	95	95	93	92	89	88	87	73
13 Mil. Pwr.	92	100	93	95	90	89	88	86	82	79	76	61
13 Afterburner	96	103	95	95	92	91	92	91	89	87	84	70
14 Mil. Pwr.	91	100	96	93	92	89	88	87	82	78	74	61
14 Afterburner	94	103	97	94	93	92	90	91	89	86	86	71
15 Mil. Pwr.	89	101	96	94	95	91	86	84	80	79	73	58
15 Afterburner	94	103	98	96	96	94	90	88	86	84	82	69

REMARKS

16 Mil. Pwr.	84	100	94	95	92	88	82	78	73	70	66	50
16 Afterburner	89	102	97	95	93	89	83	79	77	74	69	55

All SPL measurements at 250 feet distance from center of test cell at $22\frac{1}{2}^{\circ}$ increments. (sheets 1, 2 + 3)
Acoustic calibration done immediately before and after measurements (G.R. Transistor Oscillator & Sound Level Calibr
Positions 3, 4, 5 and 6 are partially shielded by other structures.
Temperature: 82 - 92 Wind: 2 - 8 knots (generally at the lower velocity) direction 230°- 190°.

Roland E. Byrd
ROLAND E. BYRD
INDUSTRIAL HYGIENIST

J-79-8 , 250'

SOUND PR... LEVEL (SPL) STUDY DATA SHEET
SOUND NAS JAX ... (3-68)

LOCATION	DATE	TIME
NAVAIREWORKFAC JAX FLA BLACK POINT TEST CELLS (EAST CELL # 1)	8 JULY 1970	0845 - 1315

NOISE SOURCE	DATA BY
J-79-8 ENGINE (Bu. No. 401649) in East Test Cell	BYRD-MORRISON-ALLEN

SOUND LEVEL METER	SER NO	OCTAVE BAND ANALYZER	SER NO	MICROPHONE
GENERAL RADIO CO.	OCTAVE	BAND NOISE ANALYZER	888	CERAMIC

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	16,000
1 Mil Pwr	88	106	102	100	99	90	84	83	82	75	70	56
1 Afterburner	94	106	102	101	99	91	88	87	87	84	84	72
2 Mil Pwr	87	104	98	96	99	91	83	82	78	73	70	58
2 Afterburner	93	105	100	98	98	92	85	85	87	84	84	72
7 Mil Pwr	94	106	102	102	96	89	91	88	84	80	78	63
7 Afterburner	100	110	104	103	99	93	96	93	93	91	93	80
8 Mil Pwr	96	108	103	105	101	93	94	91	86	85	78	63
8 Afterburner	101	112	107	107	102	95	97	96	94	94	93	81
*9 Mil Pwr ~~XFTERX~~	93	107	103	104	98	91	91	88	83	78	73	60
*9 Afterburner	100	113	109	108	101	94	95	93	93	91	91	79

REMARKS:
SPL measurements on this data sheet at 125 feet distance from center of test cell at 22½° increments, except
*9 Position at sea-wall approximately 100 feetfrom center of the test cell.

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J-79-8 . 125

SOUND PRESSURE LEVEL (SPL) STUDY DATA SHEET

SND NAS JAX 6260/2 (3-68)

LOCATION		DATE	TIME
NOISE SOURCE			DATA BY
SOUND LEVEL METER	SER NO	OCTAVE BAND ANALYZER	SER NO	MICROPHONE

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	16,000
14 Mil Pwr	91	105	102	96	98	90	88	86	84	81	80	68
14 Afterburner	97	107	104	99	99	93	90	91	90	89	89	77
15 Mil Pwr	90	105	100	99	99	91	87	85	81	77	75	60
15 Afterburner	94	106	103	100	99	94	89	88	87	86	85	72
16 Mil Pwr	90	106	102	100	99	93	85	84	82	78	74	60
16 Afterburner	96	107	103	101	99	95	89	89	88	87	86	73

REMARKS:

SPL measurements on this data sheet at 125 feet distance from center of test cell at $22\frac{1}{2}^{\circ}$ increments.
Acoustic calibration done immediately before and after meas. (G.R. Transistor Oscillator & Sound Level Calibrator)
Temperature: 82° - 89° F. Wind: 2 - 8 knots (generally at lower velocity) direction: 230° - 190°.

Roland E. Byrd

ROLAND E. BYRD
INDUSTRIAL HYGIENIST

BEST AVAILABLE COPY

To: Code 612

NAVAL AI[illegible] [illegible]WORK FACILITY, NAS JACKSONVILLE, FLORIDA (B[illegible]AC[illegible] [illegible]T. AREA)	DATE 8 APRIL 1971	TIME 1300 - 1500
J-79-10 JET ENGINE in TEST CELL (EAST) AT BLACK PT. (WITH POLLUTION ABATEMENT SYSTEM IN OPER.)		DATA BY R. E. BYRD
[illegible]VEL METER GENERAL RADIO CO. TYPE 1558-BP / SER NO / OCTAVE BAND ANALYZER OCTAVE BAND NOISE ANALYZER	SER NO 888	MICROPHONE 1560-B6 (CERAMIC)

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	16,000
1 (West Cell) at 75% ft. @ 022½°	96	94	88	88	84	84	82	80	80	76	65	46
OTHER MEASUREMENTS LISTED BELOW: J-79 at MILITARY POWER OR MILITARY POWER WITH AFTER-BURNER (EAST CELL) 1400 - 1500												
Pwr. ft. @ 022½°	86	99	87	95	94	89	85	78	76	68	57	< 44
Pwr. ft. @ 000°	81	95	86	91	88	83	81	72	66	59	45	< 44
Pwr. ft. @ 337½°	76	93	84	88	85	78	75	69	64	57	< 44	< 44
Pwr. ft. @ 315°	76 ~~77~~	91 ~~93~~	81 ~~87~~	86 ~~83~~	85 ~~86~~	85	79	71	61	54	< 44	< 44
rburner ft. @ 287½°	81	95	84	91	90	86	84	79	67	56	< 44	< 44
rburner ft. @ 180°	99	111	101	106	103	102	97	92	90	84	76	60

Distance measurements are from center of East Test Cell
Wind: Direction: 040° to 020° Velocity: 3 - 5 knots Time Period: 1400 - 1500

Analyzer calibration immediately before and after SPL measurements with G. R. Co. Sound Level Calibrator Type 1552-B and Transistor Oscillator Type 1307-A.

Roland E. Byrd
ROLAND E. BYRD

SOUND PRESSURE LEVEL (SPL) STUDY DATA SHEET
BNO NAS JAX 6260/2 (3-68)

LOCATION	DATE	TIME
BLACK POINT - 1	1-4-71	0930
NOISE SOURCE: J-79 MAX A/B		DATA BY: MOYE ALLEN

SOUND LEVEL METER	SER NO	OCTAVE BAND ANALYZER	SER NO	MICROPHONE
		1558-BP (GR)	1525	1560-P6

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTAVE BAND CENTER FREQUENCIES (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	16,000
1	95	108	99	102	103	96	88	87	85	79	75	61
2	93	108	100	102	103	98	85	87	83	80	73	58
3	86	102	96	98	99	90	81	81	75	70	64	54
4	~~86~~ 90	~~103~~ 105.3	~~93~~ 97	~~97~~ 102.3	~~96~~ 100.5	~~86~~	~~83~~ 84.3	~~80~~ 93.1	~~71~~ 78.5	~~68~~ 94.3	~~67~~ 70.2	~~50~~
5	80	100	92	98	90	82	79	75	68	66	64	49
6	93	106	96	100	99	94	92	89	83	78	75	66
7	84	106	100	102	98	88	83	76	70	64	58	44
8	94	108	101	102	106	99	91	89	85	81	74	59
9	94	108	101	101	104	98	92	92	85	80	73	59
10	95	108	100	103	104	98	92	90	85	83	76	59

REMARKS

ALL MEASUREMENTS MADE AT 250 FT FROM CENTER OF TEST CELL AT 22½° INCREMENTS

TEMP 61°F

WIND 140° - 4K

ANALYZER CALABRATED BEFORE AND AFTER MEASUREMENTS TAKEN.

PRE. .RE LEVEL (SPL) STUDY DATA SHEET
NAS JAX 6260/2 (3-68)

LOCATION: BLACK POINT - 1 | DATE: 1-4-71 | TIME: 0930

NOISE SOURCE: J-79 MAX A/B | DATA BY: MCYE ALLEN

SOUND LEVEL METER: | SER NO: | OCTAVE BAND ANALYZER: 1558-BP (GR) | SER NO: 1525 | MICROPHONE: 1560-PC

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	16,000
11	95	107	98	102	103	98	95	88	83	80	74	59
12	93	107	98	104	100	98	94	87	83	80	76	58
13	93	109	97	105	102	96	92	85	83	80	76	59
14	95	109	99	105	100	96	92	85	84	78	75	52
15	96	109	101	103	104	96	92	90	86	82	78	61
16	90	107	100	101	102	93	87	82	81	79	71	54

REMARKS:

SOUND PRESSURE LEVEL (SPL) STUDY DATA SHEET
6ND NAS JAX 6260/2 (3-68)

LOCATION	DATE	TIME
BLACK POINT 1	1-23-71	1300

NOISE SOURCE	DATA BY
J-52-8B CBC	ALLEN KuLuKowSKI

SOUND LEVEL METER	SER NO	OCTAVE BAND ANALYZER	SER NO	MICROPHONE
		1558-BP	1525	1560-PG

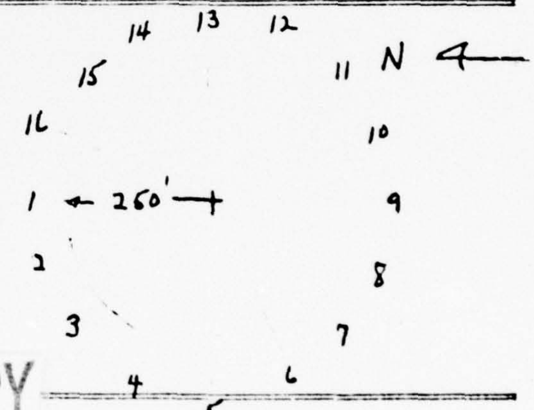
POSITION	db A "A" SCALE	OVERALL 20 Hz – 20 KHz	31.5	63	125	250	500	1000	2000	4000	8000	16,000
			FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz)									
1	84	94	90	91	89	85	78	83	74	68	59	<44
2	82	94	86	88	88	82	75	78	73	64	58	<44
3	74/80	90/93	83/86.3	84/81.6	84/87	77/81.3	69/74	71/71.3	66/71	57/63	51/56	<44
4	75	88	82	83	81	74	69	71	65	54	50	<44
5	69	85	80	83	76	71	68	65	59	53	45	<44
6	80	92	83	87	83	79	77	75	73	66	60	<44
7	74	92	85	89	84	72	70	68	64	58	55	<44
8	73	93	88	89	85	75	69	63	59	50	46	<44
9	88	94	89	90	89	83	80	76	70	63	57	<44
10	82	94	87	89	86	82	79	77	75	68	58	<44

REMARKS:

ALL SPL MEASUREMENTS AT 250 FT FROM CENTER OF TEST CELL AT 22 1/2° INCREMENTS.
POSITIONS 11-16 CONT. ON SHEET 2
CALIBRATION OF ANALYZER CHECKED BEFORE AND AFTER MEASUREMENTS

TEMP. 75°F RH. D.P. 56°F WIND: 200° 12K BAR. 30.02

CLEAR SKIES



PAGE 1

...URE LEVEL (SPL) STUDY DATA SHEET

...JAX 6260/2 (3-68)

LOCATION: BLACK POINT 1

DATE: 1-23-71

TIME: 1300

NOISE SOURCE: J-52-8B CBC

DATA BY: ALLEN KULOKOWSKI

SOUND LEVEL METER | SER NO | OCTAVE BAND ANALYZER | SER NO | MICROPHONE

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	16,000
11	87	94	86	89	90	81	82	79	79	73	63	<44
12	81	94	85	91	87	80	84	78	75	71	62	<44
13	86	96	87	94	89	80	86	79	78	72	63	<44
14	85	96	89	91	86	80	82	78	73	67	58	<44
15	84	96	90	91	89	80	82	79	74	64	54	<44
16	84	97	90	93	93	82	82	78	78	73	64	45
TOP OF EXHAUST												
STACK - LEVEL WITH												
3' FROM EDGE	108	120	112	118	113	108	110	104	100	94	90	77

REMARKS:

BEST AVAILABLE COPY

APPENDIX 13A - Page 12 of 14

SOUND PR[illegible] RE LEVEL (SPL) STUDY DATA SHEET
6ND NAS JAX [illegible] (3-68)

LOCATION	DATE	TIME
NAVAL AIR REWORK FACILITY, NAS JACKSONVILLE, FLORIDA (BLACK PT. AREA)	16 APRIL 1971	1035 - 1055

NOISE SOURCE	DATA BY
TF-30 JET ENGINE (PRODUCTION) in TEST CELL (EAST) AT BLACK PT. (POLLUTION ABATEMENT SYSTEM IN)	R. E. BYRD

SOUND LEVEL METER	SER NO	OCTAVE BAND ANALYZER	SER NO	MICROPHONE
GENERAL RADIO CO. TYPE 1558-BP	OCTAVE	BAND NOISE ANALYZER	888	1560-P6 (CERAMIC)

POSITION	db A "A" SCALE	OVERALL	FREQUENCY ANALYSIS BY OCTABE BAND CENTER FREQUENCIES (Hz)									
		20 Hz - 20 KHz	31.5	63	125	250	500	1000	2000	4000	8000	16,000
100 ft. @ 180°	90/~~84~~	105	98	103	98	95	89	81	78	73	66	51
125 ft. @ 022½°	85	98	86	95	93	87	84	78	73	69	63	48
250 ft. @ 0°	79/84	93/97	83/96	89/101	87/98	81/89	78/82	69/75	64/70	60/65	53/60	<44
250 ft. @ 337½°	76/80	90/100	82/94	87/97	84/[illegible]	77	74	70	63	59	49	<44
250 ft. @ 315°	76	89	79	85	85	77	74	72	62	52	45	<44
250 ft. @ 287½°	81 ~~90~~	90	81	85	84	79	79	78	65	53	45	<44
	77.8	90.5	81.2	86.7	85.0	78.5	76.3	72.3	63.5	56	45.5	<44

REMARKS:

Distance measurements are from center of test cell.
All SPL measurements made with engine at military poewer setting.

Wind direction: 120° Velocity: 7 knots

Noise Analyzer calibrated immediately before and after SPL measurements with G. R. Co. Sound Level Calibrator Type 1552-B and Transistor Oscillator Type 1307-A

Roland E. Byrd
ROLAND E. BYRD

SOUND PRE... LEVEL (SPL) STUDY DATA SHEET
GND NAS JAX 6260/2 (3-68)

LOCATION: NAVAIREWORKFAC JAX FLA BLACK POINT TEST CELLS (EAST CELL #1)		DATE: 15 JULY 1970	TIME: 0900 - 1000
NOISE SOURCE: TF - 30 ENGINE (Bu. No. 664252) in East Test Cell at MILITARY POWER			DATA BY: BYRD-MORRISON-ALLEN
SOUND LEVEL METER: GENERAL RADIO CO.	SER NO / OCTAVE BAND ANALYZER: OCTAVE BAND NOISE ANALYZER	SER NO: 888	MICROPHONE: CERAMIC

POSITION	db A "A" SCALE	OVERALL 20 Hz - 20 KHz	31.5	63	125	250	500	1000	2000	4000	8000	16,000
			FREQUENCY ANALYSIS BY OCTAVE BAND CENTER FREQUENCIES (Hz)									
1	84	103	99	97	95	84	80	78	76	73	73	60
2	83	101	96	94	93	85	76	76	75	73	74	63
7	90	103	98	99	93	84	87	84	84	82	82	70
8	94	105	100	100	98	88	89	88	86	86	83	72
9* (at 100')	91	105	101	102	94	89	87	86	82	80	79	67
13	92	103	100	98	93	86	85	86	86	85	84	72
14	89	103	99	94	93	86	83	83	83	82	80	69
15	87	101	98	94	94	86	82	81	79	77	76	63
16	88	102	98	97	94	92	82	82	79	78	76	63

REMARKS:

All SPL measurements at 125 feet distance from center of test cell at $22\frac{1}{2}^{\circ}$ increments (except #9 at 100 ft.)
Acoustic calibration done immediately before & after meas. (G.R. Transistor Oscillator & Sound Level Calibrator)

Temperature: 78° F to 84° F R.H.: 71% - 66% Wind: 230° - 260° 6 - 8 knots Clear skies

Roland E. Byrd
ROLAND E. BYRD

To: Code 612